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American Chemical Industry in 1915

Heraclitus, the "dark" Greek philosopher, was born some twenty-five centuries too early for the full appreciation of the fundamental idea of his doctrine: $\pi\alpha\upsilon\sigma\iota\varsigma$ $\rho\epsilon\iota$. Instead of *being*, the sole actuality is *becoming* or eternal flux and change. Harmony and unity consist in diversity and multiplicity. How Heraclitus would have been charmed by the principle of relativity in modern physics. But his greatest delight would have been modern chemistry which while dogmatizing the permanence of matter, discloses matter in its frailest and most fleeting forms of existence and reveals perpetual transitory reactions where the unskilled eye sees a dull equilibrium.

The chemical industries in America to-day reflect the transient character of chemical reactions. It would be just as ridiculous to try and say what the American chemical industries *are* at this New Year's day, as to take a single instantaneous picture out of a moving-picture show and make believe that it tells the story. And all the charm would be lost which comes from the realization of the fact that we are witnesses of chemical history in the making—nay more, strong-willed enthusiastic actors and creators.

Creators, just as Luther Burbank is a creator when he grows a spineless cactus and works other marvels in plants, fruits, and flowers. For industries grow as living organisms like plants and trees. To a greater degree than plants or trees can they be shaped by the will of man, yet they always remain children of the soil. Without the natural resources, without the markets, without transportation facilities, without labor of such psychological make-up as to adapt itself to the task in hand, the most powerful will of man is powerless. Such fundamental considerations have directed the evolution of the American chemical industries, so that this country has become the largest producer of sulphuric acid, that manufacture of cellulose and wood-distillation have made great advances, and that its splendid electrochemical industries have been created of unique scope and individuality.

When the European war cut off imports and opened to American manufacturers new and clamorous markets, the whole industrial system was upset, as though a very high tariff had been enacted over night, and a fever of activity started. And here the free creative will of the American chemist came in powerfully. The American chemist saw his duty and did it there and then. He did what was humanly possible and almost more. Our readers know how the dye problem was attacked and the potash problem, how new chemical industries were started and how the old established ones readjusted themselves to changed conditions and are

straining every nerve in incessant work day and night. Look at Niagara Falls, how the electrochemical industries have been affected almost without war orders. Our Niagara friends have only one thing to worry them—the power famine. *Quousque tandem?*

While a snap shot of all this activity would be flashy enough, it would not show tendencies. We believe evolutionary sketches of different branches of chemical activity to be published during the present year will be more welcome and more useful. We begin in this issue with a sketch of the rubber industry, which, we trust, will be found very interesting, and we also publish in full Mr. Maximilian Toch's paper on the new American barium industry, though we abstracted it quite fully right after it was presented, in our issue of Oct. 15, 1915 (page 710). Mr. Toch's paper brings out clearly and strongly one all-important point. This is a glorious but a critical period in the evolution of American chemical industries. Shall they grow? Have they been built to stay? The American chemical industry is a child of the American soil. It is part of the whole industrial organism of this country. It asks the American nation for a fair attitude of mind. It needs its intelligent support, as Mr. Toch's paper states it in detail. That it may get it, let this be our New Year's greeting to the chemical industry.

Flotation in 1915

The air has been full of flotation—and appropriately so. American metallurgists seize on any idea that promises success, and work it to the limit. A year ago copper leaching held the stage. This year it has been flotation. A year hence we can look for zinc leaching with electrolytic deposition.

Some excellent theoretical work has been done on slime in an endeavor to explain the phenomena of flotation in terms that will be acceptable to the physicist. We are now doubtful whether surface tension will completely explain it, for the exponents of an electrostatic theory, based on well known principles of colloid chemistry, are at least making us feel that their work cannot be left out of account.

A peculiar situation has developed in the wood-distilling industry as a result of the expansion of flotation during the year. For years past, pine oil has been more or less a burden on the hands of the wood distillers, as there was little market for it. Further, due to the demoralization of this industry from other causes, turpentine has been selling for several years at a cost considerably below 50 cents per gallon. And since most of the wood-distilling plants in the south had been constructed on the expectation of selling turpentine for at least 50 cents, many of them have been obliged to close. As a consequence, most of the immediately available supply of pine oil, which has accumulated for years, as well as most of the other wood-distillation products, have been consumed. Rosin, rosin oil, pine tar, pine-tar oil, wood creosote, and even crude pyroligenous acid are acceptable for flotation, so that wood distillers are now looking toward the metallurgical industry for salvation. This is only another example of

an unrelated industry receiving an impetus from unexpected metallurgical development.

On the other hand, with the price of pine and other wood oils soaring, flotation men have been turning to cheaper oils. Coal tar and fractions from the distillation of coal have been meeting with favor, the coal creosotes especially being in demand. Gas works and by-product coke works are finding markets of no small proportions for some of their products, and it is only a question of time till the treatment of these by-products from the distillation of coal will be adjusted according to the needs of the metallurgical industry, as was the production of coke. Further, petroleum producers have been wanting to get into the flotation field, but most of the petroleum products have not met with success unless mixed with a small proportion of one of the wood oils or some of the coal-tar products. Here the importance of Rittman's inventions for treating petroleum for the production of aromatic hydrocarbons may prove of importance in preparing flotation oils.

In the face of all this work with oil, comes one Louis A. Wood, of the Minerals Separation Company, with a frothing process in which no oil is used, and in which air bubbles alone do the lifting. It is yet too early to say what the effect of this invention will be, as the process is said to be a delicate one and may not succeed well enough to be applied in practice.

Oils are now being classed as "collectors" and "frothers." Coal-tar products attach themselves well to the minerals desired and are examples of collectors. Pine oil products froth well and make a desirable addition to the coal-tar products in order to get froths of varying consistency and depth. This is especially desirable in the treatment of lean ores. Other addition agents are legion. Thiosulphates and sulphites "deadened" the minerals toward flotation and are used in limited amounts for purposes of differential flotation. In the same class comes the use of bichromates for deadening galena, and permanganates for deadening zinc sulphide. Substitutes for acid are numerous, and include sodium bisulphate, any fluosilicate, aluminium sulphate, organic electrolytes such as tartrates, citrates or citric acid. In fact, many mills have now come to the use of almost no acid, or even to an alkaline electrolyte. The latter seems specially adapted to the treatment of pyrite and related minerals as well as to partly oxidized dump residues.

During the year has come the announcement that it is possible to float certain gold and silver ores in such a manner as to either displace or supplement cyanidation. Unfortunately it has not been possible to float in a cyanide solution. The importance of this development is hard to estimate, but already it is evident that it will be possible to concentrate ores containing an excess of cyanicides and obtain an enriched product that can stand the expense of special treatment which will remove the cyanicides or render them of no effect. In many instances flotation concentrates will be sent to the smelters instead of being cyanided, but in isolated places it will doubtless be best to cyanide the concentrates and thus avoid freight charges.

We have been informed that there seems to be some chance of applying flotation to the native copper ores of the Lake Superior district. This will be a step that has been needed for the recovery of fine copper which has hitherto escaped mills of the old type.

One of the most notable effects of the introduction of flotation has been the simplification of concentrator flow-sheets. This is especially noticeable in the larger copper concentrators, where the necessity of stage grinding is not so pressing as it was when we were trying to slime a minimum amount of the valuable minerals. The coincident development of roughing tables has also contributed to simplification; and now we have the phenomenon of the Anaconda company raising its extraction from 78 per cent to over 90 per cent, and doing this with a simplified mill.

The flow-sheets of the flotation sections of mills also have been undergoing standardization. As an example, the Callow cells are being used largely in sets of two cells in tandem, the first being used as a rougher and the second as a cleaner of the low-grade concentrate of the first. The middling product from the second is returned to the feed of the first. The mechanically agitated, or Minerals Separation, type of flow-sheet is of two kinds. First we have installations in which a set of from three to sixteen roughing cells produces a concentrate to be sent to a set of cleaner cells, the middling from the latter being returned to the feed of the former. The other type uses from six to sixteen cells in series, the froth from the first two, three or four being finished concentrate, while the froth from the remaining cells is returned to the feed. By this method the grade of both feed and concentrate is considerably raised. For the past few months the grade of concentrate from Butte & Superior has been 56 per cent zinc instead of 51 per cent to 53 per cent, and we understand that this is due to the adoption of a flow-sheet including roughers, cleaners and re-cleaners.

Since the development of pneumatic flotation a number of "subaeration" machines have been devised, particularly by the engineers of the Minerals Separation company. A jet of compressed air is introduced under the impellers in each cell, and this air is beaten into the pulp. This type of machine has proved very efficient, especially as a rougher. Furthermore, in this way it is possible to control aeration to any extent, making possible the application of differential flotation to mixed sulphide ores.

The present question is, What is the future of flotation? Some have been inclined to decry the importance of the process, claiming that it will not prove a panacea for the concentration of all low-grade and complex ores; but they lack caution, for we have not yet seen the end of the development along these lines. As we are only beginning to lose our fear of slime in concentrating processes, we must wait until we can see the logical result of this confidence in our ability to treat some of the most difficult products that have confronted the millman. A mill which will deliberately slime all of the ore before concentration is still as much of a novelty as were the early all-sliming cyanide mills. Fur-

thermore, we have yet to see what can be done with the complex micro-crystalline sulphides through the application of differential flotation. And lastly we have encouraging reports as to the possibility of floating carbonates of lead and copper. At least three mills are investigating this work on a large scale, using soluble sulphides to film the carbonate particles so that they can be floated.

A campaign of research and testing is on at nearly all of the larger metallurgical plants, as well as in the laboratories of ore-testing companies, consulting engineers, universities and mining schools, from all of which much good must come. We must wait a little longer before we can define the field to which flotation processes will be limited.

Precious Metal Metallurgy in 1915

A review of the past year's progress in the metallurgy of gold may well begin, as all reviews of the metallurgical year should begin, with consideration of the advance of concentration by flotation. Promising to be as epoch-making as was the development of cyanidation, its future position in gold metallurgy is perhaps not so clearly defined as its field in competition solely with gravity concentration processes: for instance, in the dressing of lead, zinc and copper ores. How far it may encroach upon the territory of amalgamation and of cyanidation is problematical, but doubtless it will in great measure determine the future trend of developments in these branches of the art. Seemingly there should be no difficulty in the flotation of amalgamable gold, and in the many instances where sulphide or telluride minerals are the carriers of the precious metals the new process may offer an economical method of either accomplishing a satisfactorily complete extraction in a single operation or of permitting secondary treatment to be confined to a small enriched fraction of the original ore, with resultant saving in plant construction and operation.

In the latter connection Mr. Butters notes difficulty in cyaniding the concentrates produced by flotation methods, particularly those containing gold and silver, and we feel that this difficulty must be surmounted before the process can win the recognition it undoubtedly merits, since the cost of marketing a concentrate would often detract from the economic success of the process. Mr. Butters' further statement that he is working in alkaline solutions, despite the early belief that the presence of acid was of prime necessity, is of more than usual interest. The effort to avoid the many practical difficulties certain to be encountered in the handling of acid solutions is well worth while and the incident illustrates anew the value of the skilled operator's experience in the organization of such experimental work.

The public has but insufficient data of flotation costs: we know of none that does not exceed the low point recorded by many mills using cyanide, so that here the newer process cannot enter except to rectify faulty extractions. However great the promise of flotation, it will not fully redeem this promise until the courts finally pass upon the ownership of the underlying patents.

Alaskan developments have reached consummation during the year and our information is to the effect that Mr. Jackling's application of copper-milling methods has been justified by results. Rolls are not to be the only machine to challenge the long maintained supremacy of the stamp mill, for the ball mill, employed years ago in Australia, is finding successful application in the same field. In the large installations of the present day the stamp mill, an inherently cumbersome machine, is at a disadvantage both as to first cost and operating cost. It is said that as compared with the ball mill it requires nearly double the mill space for equal crushing capacity and that the cost of installation is about in the same ratio. The rolls at Thane have also made splendid records, and perhaps the old machine is in greater danger of being supplanted than it ever has been before. As further invasions of its territory occur, amalgamation may simultaneously lose more ground as a primary process, since the stamp is peculiarly favored as an amalgamating device, providing at once admirable mixing of quicksilver and ore and freedom from undue "flouring" of quicksilver.

Nevertheless, such widely separated installations as the Nipissing high-grade mill and the Thane treatment of concentrates suggest that, in modified form of application, amalgamation will continue a useful tool in the hands of the well-equipped metallurgist.

Perhaps the most striking feature of all recent designing is the simplicity of the modern flow-sheet. Whether the process be crushing and concentration, as at Alaska, amalgamation and cyaniding as at the Homestake, or crushing in cyanide solution with "all sliming" as at the Hollinger and other plants, the processes and equipment are being stripped one by one of their nonessentials; and costs, responding to this analysis, are falling to levels but recently thought to be unattainable. The incomplete data available on flotation suggest that a similar winnowing is in progress here, as we note that many of the steps which Hoover's treatise deemed essentials are either being questioned or discarded. We have already alluded to Mr. Butters' efforts to avoid the use of acid; similarly the use of heat is no longer of universal application.

In cyanidation, the year has brought us little that is novel. Probably the further development of continuous counter-current decantation is the most notable feature. Patent litigation may have had its influence in hastening this development, but the process has so much to recommend it that even without the necessity of considering the question of royalties it is doubtful if filtration could in turn drive out its successor.

Several metallurgists, in discussing certain aspects of the cyanide process, have agreed that precipitation methods offer more promise of reward for the investigator than do any other phases of the process. It may be inferred, therefore, that careful study is being given to this branch of the art; yet despite this consideration and despite the abnormal prices which have prevailed in the spelter market during the past year, no developments are recorded. Zinc is still the foremost precipitant, with the dust more generally used than the shav-

ings. Aluminium powder has a limited use. The electrolytic, sodium-amalgam and charcoal methods are not in evidence, although the first two of these are, in theory, most inviting. In a characteristically thorough paper, Professor Clevenger has reviewed and discussed electrolytic methods of precipitation.

In the laboratory we note the advent of a dependable mechanical sifting device which eliminates the personal equation and the fatigue from screen analysis. A 300-mesh sieve has also been placed on the market. Both are useful additions to equipment, for we know of nothing so informative as well made gradings of the ore in various stages of treatment, and means of facilitating such inquiries have long been needed. The 300-mesh sieve has enabled us to amend somewhat our practical definition of "slime" by withdrawing a portion of the former finest product, the minus 200-mesh material, from this classification. Slime remains the unmeasurable, the "over yonder," material.

That Vesuvius of metallurgical journalism, the discussion of the law of crushing, has been quiescent during the greater part of the year except for occasional rumblings and minor flows of equations. Quite recently, however, a tremendous eruption from the foremost Kick partisan has reminded us that now, even as in the days of the Society upon the Stanislaus, the consideration of such subjects is fraught with danger. Nevertheless, we are confident that we shall hear more of it during the coming year.

Copper Metallurgy in 1915

The past year's progress in the metallurgy of copper has been along the lines discussed in our review of a year ago. At the beginning of the European war so much uncertainty existed as to the market for copper, that production by leading companies was greatly curtailed and the price of copper dropped to a low figure. This condition continued only a short time, however, for there soon came a heavy foreign demand which resulted in a recovery in price and unusual activity among copper producers. This condition is likely to continue at least until the end of the war, and possibly for some time thereafter.

The outstanding feature of the year was the general adoption of flotation, which had the effect of discouraging experimental work in hydrometallurgy, particularly where preliminary roasting of sulphides was involved. In some cases, plans already under way for copper leaching were wholly abandoned or modified in a marked degree. The result is that developments in the hydrometallurgy of copper have not shown the strides that were so confidently predicted twelve months ago. It is true that leaching is still attractive for the treatment of certain oxidized ores, and we will hear more of this work when the extreme popularity of flotation wanes. The process of Weidlein, previously mentioned in our columns, is under experimental operation, and apparently offers promise of successful development.

Flotation has found its greatest economic use in the recovery of finely divided mineral. Where the copper

minerals occur in small particles finely disseminated through the gangue, necessitating fine grinding for their liberation, or where friable copper minerals occur with other less friable sulphides, flotation is admirably adapted as a process of concentration. If, in addition, oxidized minerals accompany the sulphides, the former also may be floated after treatment with a soluble alkaline sulphide, coating or filming the particles with copper sulphide. This effects a greatly enhanced saving. Past losses in concentrating have amounted to as much as 30 and 40 per cent, due mainly to an excessive loss of the finely divided mineral; but this will be largely overcome by the use of flotation which yields a high percentage recovery on slime. The process also seems admirably adapted to the treatment of the "porphyry" ores as an initial step.

On the other hand, ores like those of the Butte district, which yield good products with jig and table concentration, require flotation simply as an auxiliary step after the use of the older standard methods. At the same time, having lost the fear of being unable to make a satisfactory recovery on slime, the upper limit of size for jigging has been greatly reduced, with the result of a greater total recovery of metal through the use of flotation. Tailing formerly carrying from 0.5 to 1 per cent copper may now be reduced to about 0.1 per cent.

The production of fine flotation concentrates has had the further effect of necessitating a greater extension of reverberatory smelting. Agglomerating methods applied to fine copper mineral to fit it for blast-furnace smelting have not been extensively applied, and it is fair to assume that by far the major portion of all fine concentrates will in the future be smelted in reverberatory furnaces.

The new furnaces, as previously noted, are much larger than the earlier types, and will permit a continuous flow of slag. The new method of charging along the full length of the side walls also renders unnecessary the frequent fettling called for under former practice, because the charge banked up against these walls affords a protection from slag corrosion.

The present tendency is toward coal-dust or oil firing of reverberatory furnaces, depending on the location of the plant with respect to fuel supply. In some localities coal of any grade is expensive while oil is relatively cheap, and under such conditions it is doubtful if coal-dust firing can find favor. Excellent fuel ratios are obtained under either system. Other advantages are found in an increased tonnage; maintenance of a higher temperature; requirement of less draft than with ordinary grate firing.

The requirements for oil-firing are comparatively simple. The oil is preheated to a temperature ranging from 160 deg. Fahr. to 200 deg. Fahr. at different plants, and is fed under a static pressure of from 35 to 40 lb. In the burners the oil is atomized by air at 40-oz. pressure.

Coal-dust firing is not new in its inception, but early trials were failures because many of the features essential to success were not understood. These features

are: drying the coal to 1 per cent or less moisture; fine pulverization, so that 93 to 97 per cent will pass 100-mesh, and 82 per cent is finer than 200-mesh; proper proportioning of fuel and air; use of fuel with 20 to 30 per cent or more volatile matter; correct design of the furnace and provision for taking care of the ash formed.

While blast furnaces are being discarded in certain plants, they are indispensable where low-grade high-sulphur ores are available, as at Mt. Lyell, Tasmania, and where pyritic or semi-pyritic smelting can be practised they bid fair to remain in use as long as suitable ores can be found.

In the realm of crushing and grinding for concentration there has been a steady development of ball mills of various types. The principle feature of their construction is a lowering of the point of discharge as compared with that of feed. In some case this is accomplished by means of lifting devices in the discharge end, while the extreme suggestion is for the use of an open-end discharge. Disk crushers and grinders also have been receiving favorable consideration for both coarse and fine work. These machines offer the advantage of giving a true crushing action without grinding by abrasion also, and for certain purposes this effect should be valuable.

The Year in Zinc Metallurgy

The logical sequence of the unusually high price for spelter during 1915 was a stimulus, not only to ordinary retort smelting but to the development of other methods of reduction and the utilization of low-grade ores. Smelting plants which had been abandoned for years were rehabilitated, and some new construction was completed. The Donora plant of the United States Steel Corporation was brought into production in the record time of four months and ten days from the time of beginning construction, or in about one-fourth the normal time for the construction of such a plant. An unusual feature of this smelter is the extensive use of concrete in its construction.

The Joplin district profited tremendously from the high prices which prevailed, and the construction of new concentrating plants has exceeded any previous record. The later plants are of good design and should effect a higher saving, particularly on slime, than has been customary in the older mills.

In the field of dry concentration and separation, there have been no new developments beyond the standard electrostatic and electromagnetic machines and the Plumb pneumatic jig, all of which are now well known.

During a year which gave promise of definite results from electrothermic smelting, there was little or nothing forthcoming, and at the time of writing much more interest centers in electrolytic zinc. The present position of these two processes is quite reversed from that of a year or two ago. At that time electrolytic methods were not received with much favor by some of the largest zinc-producing concerns on account of the high capital cost for plant, whereas electrothermic smelting was conceded to be promising for the treatment of

mixed sulphide ores of zinc, copper and lead. To-day, although electrothermic reduction still holds its possibilities, it is not as near commercial reality as is the other process. Some of our largest and most progressive metallurgical organizations have undertaken the leaching of zinc ores, with electrolytic deposition, and have experimental plants under operation. The article by D. A. Lyon, O. C. Ralston and J. F. Cullen on hydrometallurgy of zinc and lead in 1915, published elsewhere in this issue, will be found particularly interesting in this connection.

The zinc oxide plant at Leadville, already described in this journal, has afforded an outlet for a small tonnage of low-grade carbonate ore. The product has been in steady demand, finding its way into the chemical trade.

Calcination of zinc carbonate ore for the purpose of enriching it by expulsion of carbon dioxide is not as extensively practised in this country as in Mexico. In the latter country the process has been perfected to a satisfactory point and is in operation at several places. In the United States the only calcining plant of which we have knowledge is that of the Empire Zinc Company, in Nevada. Coarse ore is calcined in a vertical kiln, and the fine in a rotary furnace. The success of the process in Mexico seems to be due to the peculiar form of kiln used and the careful manner in which the charge is fed by hand. For the latter purpose cheap labor is an essential.

Needless to say, flotation has played a conspicuous part in the concentration of zinc ores, greatly increasing the recovery. Experimental work on the flotation of carbonate ores is proceeding, with better prospect of success than could be reported a year ago. Just how much zinc has been added to our total output as a result of flotation is difficult to estimate, as the use of the process has so modified the previous milling practice that the mineral actually recovered by flotation is probably much more than that which was counted a loss in former practice, and which flotation was first expected to save. In any event, the total must represent an appreciable percentage of our total production.

Chloridizing and other special processes have been quiescent during the year, but their exponents are still active and promise developments in the near future. At the present time active experimentation is a negative quantity.

The Steel Trade's Wonderful Year

To reach a correct conception of the influence responsible for the remarkable showing made by the American steel industry in 1915, its change from a rate of operation less than 35 per cent of its capacity to a rate of operating under the highest pressure it ever knew, the most direct method seems to be first to analyze the character of the demand at the close of the year, to consider the precise position attained before endeavoring to trace the steps. One reason for adopting this course is that during the year the impression arose that steel activity was due in large part to orders for "war steel" and while that view may have been substantially correct at one

time it was not correct as to conditions in the late months of the year. If the influence of orders for war steel is rated too highly, the easiest method of correcting the misapprehension is to consider conditions in the steel market at the close of the year.

Steel, of course, is involved in two classes of exports, the steel exported directly from the mills and reported by weight in the government's export statistics, and the steel which passes to various manufacturers and is converted into merchandise that is exported. The iron and steel exports returned by weight increased steadily during the year until August, when they reached a maximum of 406,000 gross tons. There was a decline to 382,000 tons in September and a further decline to 351,000 tons in October. Excluding from the October returns pig iron, scrap, iron castings, etc., there was about 300,000 tons of finished steel, representing a rate of 3,600,000 tons per annum. Steel production increased from August to October, so that the percentage of steel exported decreased very materially. Steel shipped by mills for indirect export can be estimated only very roughly. It includes steel for shells, arms, locomotives, freight cars, automobiles, machinery, etc., but an estimate of 300,000 tons a month seems high. If we assume that the total steel made in October for export, direct and indirect, was at the rate of 7,000,000 tons a year, it represented no more than 25 per cent of the production, which may safely be estimated at about 28,000,000 tons a year, in terms of finished rolled steel. The remainder passed into purely domestic use. In November a serious freight congestion began to develop between mills and tidewater, resulting early in December in the railroads placing embargoes on shipments of steel intended for export. Shipments of the mills for export were thereby reduced, while shipments to the domestic trade were correspondingly increased, and yet the domestic trade was not glutted, but called for more steel. Thus the condition at the close of the year was that steel-mill shipments represented something like 80 per cent domestic and 20 per cent export, direct and indirect. A portion of the export material, furthermore, was not war material.

The domestic steel-consuming trade had thus become a very large buyer. There were two chief causes for the remarkable improvement that occurred during the calendar year 1915, one being that in the closing months of 1914 industry had passed far below normal and could not but react, the other being that the tremendous export trade of the country was making it prosperous. The war produced a mental panic, which reached its worst stage perhaps at the close of October, 1914. There would have been more than a mental panic if the stock exchanges had not been closed and the new banking system had not been scheduled to go into effect on Nov. 16. While industry was generally depressed, the buying of steel reached a lower ebb than corresponded to the amount of industrial activity, because jobbers and manufacturing consumers reduced their stocks. In our review of a year ago, explaining the extreme depth of depression to which the steel trade had fallen, it was pointed out that fluctuations in steel production were

due in considerable part to the fact that in this industry the buyer rather than the seller carries stocks.

In December, 1914, a moderate amount of steel business was booked, at prices which averaged, for the various finished products, a somewhat lower level than that which obtained in November, 1911, and were therefore the lowest in more than 15 years. The mills were operating at less than 35 per cent of capacity. The business booked was chiefly for January and February shipment. The mills then succeeded in mustering sufficient courage to advance bars, plates and shapes from 1.05c. to 1.10c. on Jan. 1, a proceeding which gave some encouragement to the trade at large. By very easy stages other price advances were made during the half year. It was recognized that the preceeding was somewhat unusual, for the history of American steel markets in general shows that prices have no inherent strength, or at least advancing tendency, unless the mills are operating at about 85 per cent of their full capacity.

A remarkable part was played by "war orders" for steel during the second quarter of the year. While such orders had been placed at intervals the bearing upon the market as a whole had not seemed important. In April reports were circulated of very large tonnages of shrapnel rounds being sought, both for direct export and for shell manufacture in the United States. In many quarters these reports were not taken very seriously. Secrecy surrounded the placing of many of the orders, but in the course of a few weeks domestic buyers of steel came to realize that the war business really was important. In May and June orders were placed for fully 50,000 freight cars, about one-third being for export, these orders being more than double the total placed in the nine months from the inception of the war up to that time. The fear that the war demand for steel might make steel scarce in the United States, the encouragement given by the resumption of railroad buying, and some minor influences, gave a very decided stimulus to steel demand in general. Steel mills operated at close to 85 per cent of capacity in July and in August they reached substantially full operation. Deliveries began to fall behind and buyers then took hold with vigor.

Steel prices, which advanced rather haltingly during the first half of the year, and then only by an average of about \$2 a ton, began to advance more rapidly, and in October an unprecedented rate of advance was developed. Steel prices rose during the last three months of the year at an unprecedented rate, barring only the altogether exceptional advance of 1899.

The mere volume of demand was not sufficient to account for the exceptionally rapid advance in these three months. There was an abandonment of the policy pursued by steel manufacturers in various other periods of heavy demand, that of holding prices down to what was regarded as a fair normal level. The decision rendered June 3, 1915, in the case of the Federal government against the United States Steel Corporation had given the corporation itself a clean bill of health, while it had roundly condemned the "Gary dinners." The steel makers felt that they were perfectly free to allow prices to advance indefinitely, if they tended to do so; that as

they were denied the privilege of holding them up to what they considered a normal level, in times of poor demand, there was no occasion to hold them down to such a normal level in times of good demand. There was the further influence that the demand for steel was regarded as largely a creature of the war, that a termination of the war might greatly reduce the demand. The advances in finished steel prices during the second half of the year averaged about \$11 per ton, making about \$13 advance for the whole year. The advance could be regarded as still greater if account were taken of the premiums paid for prompt deliveries in the case of some products. The level at the close of the year was a trifle above the top point reached in 1907 and therefore represented the highest level since 1902. Prices were about \$6 a ton above the top reached in the 1912 movement and about \$4 a ton above the highest level reached in the movement of 1909.

As already indicated there was a decided increase in domestic buying in the mid months of the year, due in considerable part to sentimental influences. Such buying would in the course of months play out; buyers would become stocked with material, but no such playing out has occurred. No stocks to speak of seem to have been accumulated; on the contrary many buyers are clamoring for better deliveries. The actual consumption of steel has evidently greatly increased.

For many decades, through the year 1907, the demand for iron doubled on an average once in each ten years, though far from regularly year by year. It becomes impossible to judge at any time what is the normal demand, to determine whether a given demand being then experienced is normal, below normal, or above normal. There was a period of twelve consecutive months ending October, 1907, in which the production of pig iron was 27,000,000 tons. The existing capacity, eight years later, is 38,000,000 tons or thereabouts, representing a considerably smaller increase than would be represented by a doubling in ten years. A demand that fully engages the existing capacity may not be an abnormally heavy demand at all. It is a fact that a considerable number of the steel consuming industries are but indifferently employed. The demand for structural steel, for instance, has been conspicuously light.

Perhaps it is no great measure of prosperity in the consuming trades that has made the steel industry itself so prosperous. The prosperity of the country at large is traceable to the enormous balance in its merchandise trade. In the twelve consecutive months ended with November the merchandise trade balance in favor of the United States exceeded \$1,700,000,000. For a number of years an apparent favorable balance in merchandise of about \$500,000,000 served to equalize the unseen balance. A balance \$100,000,000 a month greater naturally induces prosperity.

Pig-iron production in the United States was 12,233,791 gross tons in the first half of 1915 and about 17,700,000 tons in the second half, making about 29,900,000 tons for the year. The record calendar year was 1913, with 30,966,152 tons, the record half-year being the first half of 1913, with 16,488,602 tons to its credit.

Readers' Views and Comments

Nomographic Charts for Conveyor Belt Calculations

To the Editor of Metallurgical & Chemical Engineering:

SIR:—I have studied with much interest the chart for the quick calculation of problems relative to rubber conveyor belts which was published in the Nov. 1, 1915, number of METALLURGICAL & CHEMICAL ENGINEERING. The graphical method of representation is finding new applications every day and Messrs. J. D. Mooney and D. L. Darnell have given us a very good example of the rectangular co-ordinate type of chart. It has appealed to me, however, that the equation in question is admirably suited to another type of graphical solution, namely, the nomographic chart, and with the idea of calling attention to this second graphical method, I have constructed the charts, reproduced on page 9.

Fig. 1 is a nomographic chart for the solution of the same problem as that treated by the aforementioned authors, namely, the determination of the correct number of plies for a rubber conveyor belt operating under certain conditions. The equation represented is given by them as

$$p = KgW(L + 10H)$$

where

p = the correct number of plies.

K = a constant depending on the type of drive. For a simple drive with a bare pulley, it has the value $1/250,000$.

g = the weight in pounds per cubic foot of the material handled.

W = the width of the belt in inches.

L = the length of the belt in feet (approximately twice the center distance).

H = the difference in elevation between the head and tail pulleys in feet.

The nomographic chart consists of three scales and one supporting line BB . On the scale AA is the length factor f equal to $(L + 10H)$, on the scale CC , the width of the belt W and also the weight of the material g , and on the scale DD is the number of plies p . To solve the equation for p , knowing the other variables: Place a straight edge across the chart connecting the points representing W on the scale CC and f on the scale AA ; place a pencil point on the intersection of this line with BB and swing the straight edge till it connects this point with the point on CC representing g ; where this line intersects the DD scale read off the correct value of p .

For example, take the same set of values used to illustrate the rectangular chart, width 36 in., length 300 ft., difference in elevation 20 ft. and material, sand and gravel. The arrow pointed lines show the solution of this problem. Connect a (500 on AA) with c (36 on CC); connect b , the intersection of this line with BB , with c (90 on CC) and note that d on DD falls between 6 and 7 indicating that 7 is the proper number of plies. Note that it is unnecessary to actually draw the lines connecting the points.

The advantages of the nomographic as compared to the rectangular co-ordinate chart are briefly these:

1. It is easy to construct; but few lines are necessary to represent a formula and the calculation is simple.

2. It is easy to read; it does not present a mass of lines to the eye.

3. It is easy to interpolate; interpolation is always easier on a scale than between lines on a plot.

4. The solution is equally simple whichever quantity is the unknown.

5. Any number of variables can be accommodated.

The rectangular chart for the solution of the formula was for but one drive only, and the value obtained by it had to be multiplied by a conversion factor if a calculation for one of the other types of drive was desired. The nomographic chart can be made to accommodate the added variable by merely adding another scale and line. Fig. 2 shows this chart arranged to accommodate the varying K . To solve the same problem as before, connect a (500 on AA) with c (36 on CC); connect b , the intersection of this line with BB , with c' (90 on CC); connect b' , the intersection of this second line with $B'B'$, with a' ($K = 1/250,000$); this line cuts out the correct value of p on DD .

The nomographic chart is especially applicable to exponential and power equations and a study of its utility in this direction is well worth while.

ROBERT E. HAYLETT

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Massachusetts Institute of Technology,
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What Is the True Value of a Complex Ore?

To the Editor of Metallurgical & Chemical Engineering:

SIR:—From time to time I have noticed articles by many different engineers and metallurgists on the subject of "Mine Valuation." I do not recall having seen anything in the nature of a discussion of "Ore Valuation." Since my work for the past thirteen years has been almost entirely along the lines of valuation of complex ores, especially those containing zinc, I propose to open a discussion by submitting the following:

Having worked out the treatment of several "complex ores" and having attempted to devise a treatment for several hundred others, I have taken a specific case which has come to my personal attention and which, I believe, will serve the purpose of argument more completely perhaps than a general discussion of the subject.

During the greater part of the present year, owing to the unusual activity in the zinc industry, engineers have had many occasions to examine and report on mines, the values of which depend to some extent on the zinc contents of the ores. The mine is sampled and the ore assayed and measured to a point where the engineer finds a certain number of tons carrying a certain amount of gold, silver, copper, lead, zinc, iron and any other metals that can be recovered and sold. It is at this point in his examination that an understanding of the methods of treatment to be employed that will effect a commercial saving of the metals, the cost of such method and the marketing of the products, is fully as essential to the correctness of his findings as is the knowledge of methods for sampling, assaying and measuring the ore.

It is at this point also that the assayer has found himself in a most embarrassing position; not on account of his inefficiency as an assayer, but because he has not the facts at hand upon which to base a sound opinion as to the value, in dollars and cents, of the ore upon which he has determined the metal contents. I have seen assay certificates from reputable assayers which showed fully the metal contents, and in the space for that purpose was shown a value which had been calculated from the analysis. In many cases these "values" have been found to represent the metal values, based upon the current market quotations for the dif-

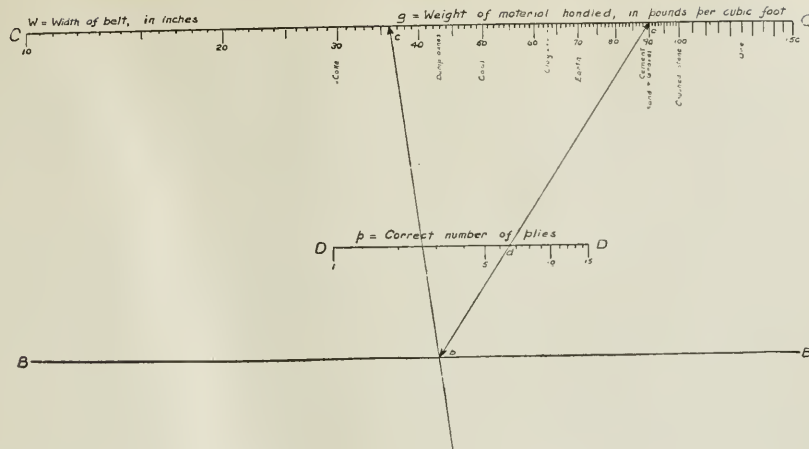


FIG. 1—CHART FOR CONVEYOR-BELT
CALCULATIONS, CONSTRUCTED

BY R. E. HAYLETT

$$p = kgW(L + 10H)$$

FOR A SIMPLE DRIVE WITH BARE PULLEY

$$K = 1/250,000$$

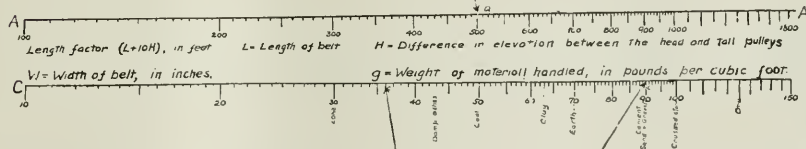
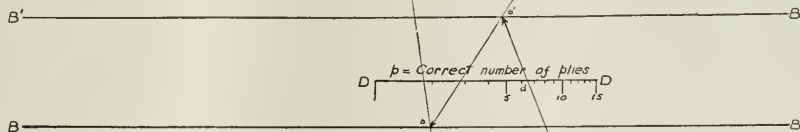


FIG. B—CHART DRAWN
FOR VARIOUS DRIVES

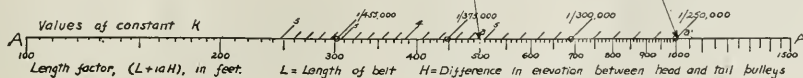


$K = 1/250,000$ for a simple
drive with bare pulley

$K = 1/300,000$ for a simple drive
with rubber-lagged pulley

$K = 1/375,000$ for a tandem
drive with bare pulleys

$K = 1/450,000$ for a tandem drive
with rubber-lagged pulleys



ferent metals delivered in New York. It is needless to say that this method is misleading and may result in great financial disaster if further investigation is not undertaken.

Many engineers have attempted to estimate such ore values by allowing "liberal" losses. By this method great mistakes may be made chiefly because the losses allowed have not been sufficiently liberal. It is my intention to try to show that there is no possible way by which these losses can be estimated. They must be accurately determined, and in most cases, they will be found to be surprisingly large.

Some months ago I was asked by an engineer who had finished an examination, what percentages of saving could be reasonably expected by the most modern practice. I was told that the ore had a value of \$12 per ton, based on a price of \$20 per ounce for gold, 50 cents for silver, 50 cents per unit for lead, and 60 cents per unit for zinc. He had not assayed for iron since it had little value. I was unable to make an estimate for I did not know, nor did any one know, what grades of products could be made or how much of the gold and silver would be found in the zinc product. These facts, which are absolutely essential, can be determined and must be determined before the value of the ore can be definitely fixed.

To illustrate how difficult it would be to estimate a value of this kind, I submit the following table to show what products can be made and what money will actually be received at a certain stage of the metal market, for a certain ore.

	Wt.	Oz. Au	Oz. Ag	Per Cent Pb	Per Cent Zn	Per Cent Fe	Per Cent SiO ₂
Original ore.....	100	0.07	9.00	8.00	16.00	7.00	46.00
Lead product.....	3	0.32	45.00	68.00	5.00	6.00	2.00
Per cent saved.....		36.50	40.00	68.00	2.50	6.80	0.30
Iron product.....	14	0.22	17.00	8.00	11.00	32.00	6.00
Per cent saved.....		44.60	26.40	14.00	9.50	64.00	1.80
Zinc product.....	26	0.02	6.50	2.60	48.00	5.00	10.00
Per cent saved.....		8.50	19.00	8.60	78.00	18.50	5.60
Silme.....	7	0.04	11.00	7.00	12.00	6.50	49.00
Per cent saved.....		4.00	8.50	6.10	6.20	6.50	7.40
Tailing.....	45	0.01	1.20	0.60	1.70	0.70	86.00
Per cent lost.....		6.40	6.00	3.30	4.70	4.20	84.90

It will be seen that the total concentrate carries 89.6 per cent of the gold, 85.5 per cent of the silver, 90.8 per cent of the lead and 90.1 per cent of the zinc. This can certainly be called a high saving.

The original ore has a value of \$29.10, estimated upon metal contents and quotations, with gold at \$20 per ounce, silver at 50 cents, lead at 4½ cents per pound and zinc at 5 cents. Estimated with gold and silver at the same value as above, and lead at 50 cents per unit and zinc at 60 cents per unit, it has a value of \$19.50. When the products are sold, however, they will be sold about as follows:

In lead concentrate we will receive \$19 per ounce for gold, 47½ cents for silver, 3¼ cents per pound for 90 per cent of the lead (wet assay less 1½ per cent), 10 cents per unit for excess iron. We will pay \$3 freight and no treatment charge. This leaves us \$63.75 per ton net, or \$5.10 per original ton.

Iron concentrate will bring the same prices for gold, silver, lead and iron. We will pay same freight and about \$5.50 for treatment. This leaves \$11.31 per ton net, or \$1.57 per original ton.

The zinc concentrate, with spelter at 5 cents, and \$5.50 freight, will net \$19.30 per ton or \$5.02 per original ton.

These net receipts amount to \$11.69 per original ton, which is 31 per cent of the assayer's figure and about 60 per cent of the engineer's.

A careful analysis of all of the above figures will show that we have received net, \$11.38 per ounce for gold, 25.2 cents per ounce for silver, 2.09 cents per pound for lead, and 1.57 cent per pound for zinc, which figures may be

safely applied to this particular ore so long as the grade does not change materially. The contracts upon which I have figured settlements may vary to some extent, but the general result will be about the same.

From the above it will be apparent to the investor and to his engineer that the metal contents and market prices of the metals cannot be used as a basis of calculation of ore valuation until it is fully and definitely known where these metals will be recovered and what prices will be received for the various products.

Denver, Col.

A. M. PLUMB.

The Iron and Steel Market

The steel market turned quiet in the second half of December, but without losing a particle of its fundamental strength, the quietness being attributed to the usual holiday influence. Specifications on contracts expiring at the close of the month were as heavy as formerly, except for the influence that some buyers had already specified their limits. Most of the contracts, of course, were at relatively low prices.

On Dec. 15 the Carnegie Steel Company advanced its minimum price on bars, plates and shapes from 1.70c. to 1.80c., and as some of the other mills had already made such an advance the market became quotable at 1.80c. as minimum. Effective Dec. 21, the American Steel & Wire Company advanced wire prices \$2 a ton, other mills immediately concurring.

The steel mills enter the new year with a very large volume of specific business on books, actual orders which were taken with the understanding that they were not to be canceled or the price revised no matter what occurred in the market. There is also a large volume of contract business upon which heavy specifications can reasonably be expected. The steel producers feel confident that, barring actual accidents in the market, they will be called upon to operate at their fullest capacity throughout the year 1916. All are careful, however, to avoid making the semblance of a prediction as to what may occur when the war ends. Now that a much smaller proportion than formerly of the total steel output is passing into war material, the question of the possible cancellation of war orders is relatively insignificant. The great question is the general economic changes that may be wrought, affecting the various industries of the United States. There is also the question of foreign competition, not only in neutral markets but possibly even in the markets of the United States. There will be a feverish revival of commercial activity in the belligerent countries, but there is a wide range of opinion as to whether this will be on a basis of high costs or low costs. All eyes will be turned to the United States as the place where the money lies. If the production of steel abroad is resumed more rapidly than the consumption there is the possibility of the offering of such steel greatly disturbing the markets in the United States.

Production of pig iron and steel has not been materially increased since October, a rate of substantially full production having then been reached. A few additional units have become productive, and others have been speeded up somewhat, but the weather, of course, has been less favorable than in September and October, and it may be said that production has been at an unchanged rate, with no prospects of material change.

Pig Iron

The various pig-iron markets have continued their advances, though as formerly without the stimulus, apparently, of any really large buying. Unless the advances represent an unusual amount of courage on the part of the furnacemen, an unprecedented hopefulness for the future, one must conclude that the trade is

facing a definite scarcity of pig iron, as there has been for four months a scarcity of steel. Pig iron has now advanced, since the low level maintained so consistently during the late months of 1914 and the first six months of 1915, fully \$5 a ton. Such an advance is quite unusual. A moderate increase in demand serves to advance prices moderately, say, by from \$1 to \$4 a ton, merely through the operation of an economic law that as demand increases the less fit furnaces, with higher production costs, must be brought into operation. The market is now quotable as follows: No. 2 foundry iron, delivered Philadelphia, \$19.25 to \$19.75; at Buffalo furnaces, \$18; delivered Cleveland, \$18.80; at Chicago furnaces, \$18 to \$18.25; at furnaces, Birmingham district, \$14 to \$15; f.o.b. valley furnaces, 95c. higher delivered Pittsburgh: Bessemer, \$19.50 to \$20; basic, \$18 to \$18.50; foundry, \$18.50 to \$19; malleable, \$18 to \$18.50; forge, \$18 to \$18.50.

Steel

Since the scarcity of steel became acute there has been no regular open market for soft steel billets and sheet bars. The regular consumers were covered fairly well by long-term contracts, generally subject to a periodic adjustment of price, and the mills would not sell in the open market, or at least at such prices as would be paid by any considerable number of possible buyers. The pressure for billets has been accumulating, however, and some purchases of open-hearth are being made. One sale of about 2500 tons of soft open-hearth billets was made after the middle of December at \$35, maker's mill, Pittsburgh district, and that may perhaps be regarded as fixing a market. Bessemer billets are quotable at \$32 to \$33, with but little tonnage available at that range. There is no demand for sheet bars at such prices, since prices obtainable for sheets and tin plate would not justify, and the consumers simply depend upon such steel as they obtain on their regular contracts. Rods are about \$40 and forging billets about \$50 to \$55.

Finished Steel

Premiums for prompt shipment of plates are the rule, 2.25c. to 2.50c. being paid for small lots. Premiums are also occasionally paid for steel bars. Regular mill prices, f.o.b. Pittsburgh unless otherwise noted, are as follows:

Rails, standard sections, 1.25c. for Bessemer; 1.34c. for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 1.80c.

Shapes, 1.80c.

Steel bars and bands, 1.80c., base; steel hoops, 2c., base.

Iron bars, 2.009c. to 2.059c., Philadelphia; 1.75c., Chicago; 1.85c. to 1.90c., Pittsburgh.

Plain wire, 1.95c., base; galvanized wire, 2.65c.; wire nails, \$2.10 per keg, base; painted barb wire, 2.25c.; galvanized barb wire, 2.95c.

Sheets, blue annealed, 10-gage, 2.25c. to 2.75c.; black, 28-gage, 2.60c. to 2.70c.; galvanized, 28-gage, 4.75c. to 5c.; painted corrugated, 28-gage, 2.80c.; galvanized corrugated, 28-gage, 4.80c. to 5.05c.

Tin plate, \$3.60 for 100-lb. cokes.

Steel pipe, ¾ to 3-in., black, 78 per cent off list; galvanized 73½ per cent off list.

Boiler tubes (less than carloads), 68 per cent off list.

Structural rivets, 2.50c.; boiler rivets, 2.60c.

Cold-rolled shafting, 50 per cent off list.

Cold-rolled strip steel, 3.50c., base.

Non-Ferrous Metal Market

Dec. 27.—Unusual existing conditions are reflected in the metal market which is about as uncertain as the weather. Under normal conditions the last weeks

of the year would be dull. The present market made a good start in this direction early in December, but the dullness was not sustained and heavy sales have been made during the last two weeks, especially in copper, forcing this metal to a very high level.

Copper.—The price has been held at close to 20 cents all during December up to last week, when large sales forced the price to 21½ cents. On the 22nd, 60,000 tons was contracted for by England for 1916 delivery, at a price said to be 21 cents delivered. Producers control the market and the metal is liable to remain in a very strong position for some time to come. Exports for November were 23,168 tons of 2240 lb., while exports for December are running considerably ahead of November.

Tin.—The price of tin has moved within a comparatively narrow range in December, buyers refusing to become excited. Doubtless they are tired of being misled by the many wild rumors. An absence of inquiry characterized the market early in December. On the 16th England announced the curtailing of exports, which, while it excited the market some, only caused a 1¼-cent advance, and toward the latter part of the month a reaction took place. Prices varied between 37.25 and 40.00 for spot during the month.

Lead.—The Trust price was raised by 0.15 to 5.40 on Dec. 14. The market is in a strong position and the advances recently made were expected. December exports are running ahead of November, which were 5423 tons.

Spelter.—The decline of 3 cents per pound which took place in a few days around Dec. 1 lowered the price to about 15 cents. Sellers became excited and attempted to unload their stocks. By the middle of the month sellers were refusing to quote, which shows how erratic the market is, or how erratic it is being made. For several days sellers refused to quote, consequently the market became excited and the price advanced to about 17.50 cents spot with slight variations up and down. At the time of writing spot spelter was 17.35-17.50.

Other Metals.—Aluminium held up well until Dec. 20, when the extreme dullness caused a decline, which forced the metal to 53.00-55.00. On the 27th it was quoted at 54.00-56.00. Antimony remained practically unchanged during December at 39.00-39.50 for both American, Chinese and Japanese. Silver was up to 56¼ on Dec. 6, since when it has gradually dropped to 53¾. Tungsten continues at about \$60 a unit for concentrates, platinum prices are nominal at \$88 to \$100 per ounce. Quicksilver is quoted at \$125-\$130 per flask.

One Hundred and Twelfth Meeting of American Institute of Mining Engineers

The 112th meeting of the American Institute of Mining Engineers will be held in New York City, Monday, Feb. 14, to Thursday, Feb. 17, inclusive. The committee on arrangements consists of David H. Browne, chairman; Bradley Stoughton, vice-chairman; Lawrence Addicks, P. E. Barbour, G. D. Barron, J. V. N. Dorr, J. R. Finlay, L. D. Huntoon, Burr A. Robinson, E. M. Shipp, Joseph Struthers, E. B. Sturgis and R. H. Vail.

A smoker and entertainment will be held on Tuesday evening, Feb. 15, which the committee in charge promises will be well worth attending. The annual dinner will be held at the Hotel Astor on Wednesday evening, Feb. 16, and the presence of ladies is urged. The dinner will be followed by dancing.

The entertainment of the ladies will be in charge of

the Ladies' Committee, of which Mrs. Louis D. Huntoon is chairman. A very complete program of entertainment has been provided for the ladies, including luncheons, teas, dances, theatres and a visit to the art galleries of Senator Wm. A. Clark. The ladies are also especially urged to enjoy the all-day boat trip which has been arranged for Thursday. By courtesy of the Secretary of the Navy a naval vessel will be provided for a cruise around the harbor. The firing of some of the large guns will be witnessed.

Monday evening, Feb. 14, will be "college night." A Committee on Reunions, of which Dr. Joseph Struthers is chairman, will be in charge. It is expected that many formal gatherings of college alumni will be held.

Many clubs kindly offered the extension of privileges to members last year, and it is expected they will do the same this year. All the facilities of the United Engineering Building will be at the service of the members and their guests, and from the looks of the preparations which are being made a very interesting and comfortable time should be had by all those attending.

The technical program will contain many interesting papers in the various sections on the different metals, petroleum and gas, mining and milling methods, coal, coke, geology, etc.

Meeting of the Naval Consulting Board

The U. S. Naval Consulting Board was in session on Dec. 22 and 23. The first day was mainly devoted to meetings of the different sub-committees, where general pending subjects were discussed and further steps were proposed for future work. On the evening of Dec. 22 the members were the guests at a short informal monthly dinner of the American Institute of Mining Engineers and then promptly left for the general meeting of the board.

The next day was devoted to an inspection of the submarines and battleships now assembled at the Brooklyn Navy Yard, after which another general meeting was held. At the meeting, the laboratory committee, consisting of Edison, chairman, and Baekeland, Whitney and Woodward as members, presented its final report and recommendations, which were accepted with much enthusiasm by the other members of the board as well as by the admirals who were present at the discussion. The laboratory provides for adequate facilities to make all tests and experiments relative to the construction and operation of men-of-war or ordinance and ammunition without the present delays which hamper so much the construction work of anything new and which compel postponement of trials of things until it is too late to make a change. In this respect alone the proposed laboratory would introduce an enormous saving of expenses aside from preventing the present unavoidable delays in the construction of our means of defense. Some time ago a firm which was more than one year behind in its deliveries, simply answered that the construction work involved a set of new devices, each of which involved serious problems which delayed the work, because the necessary data had to be gathered during construction work, which increased enormously the cost as well as the period of construction.

Among other reports which were communicated, we should mention the recommendation by the sub-committee on ordinance and explosives, that the Government of the United States should erect at least one unit for the synthetic manufacture of nitrates or nitric acid, so as to get at least one plant, however small, in which to learn to produce the indispensable chemical for the manufacture of smokeless powder or modern explosives. This unit would permit to train a staff of competent

engineers or chemists to acquire the necessary experience and to provide means so that in time of war immediately other units could be added in a relatively short time. The plans, drawings, and specifications would be prepared in advance for such an emergency, and the initial staff would be able to train additional men for the work.

As matters stand now, it would be of little use to be equipped with best guns and warships as long as an enemy could easily seize the nitrate fields of Chile or occupy the ports of shipment of the valuable material. At present this country can provide within itself practically all other indispensable materials for war, except nitrates. Private industry has not gone into the matter of synthetic nitric acid here in the United States, because it can find better employment for capital in other chemical industries as long as it is so cheap and easy to import natural Chile saltpeter.

The Government might be able to run the enterprise at a small profit, or even at some loss, and use the produced nitrate for its own smokeless powder and explosive plants, or sell it as fertilizer and charge the relatively small investment as part of its equipment for defense while at the same time keeping abreast with an industry which ultimately may have an immense importance as a supply of cheap fertilizer for agricultural purposes.

The United States can well afford in its policy of conservation to set apart for this purpose one of the large water powers under its control.

The committee on manufacturing and standardizing is busying itself with extending the rational methods of manufacturing now adopted by the automobile manufacturers of this country to the rapid manufacture of aeroplane motors, and also proposes means whereby men of the army or the navy who want to become proficient in aeronautics will have the benefit of the unusually well provided instruction classes of the associated automobile manufacturers of this country free of charge to the Government.

In further accord with the idea of mobilizing the industries of the country a definite plan is being developed whereby the whole United States is divided into sections, and in each section a census is to be taken of the different industrial establishments and their equipment, and, furthermore, all necessary information is to be furnished to the manufacturers so as to enable them to convert their plants at shortest notice in time of war to contribute with best efficiency to the manufacture of ammunition and general supplies.

We are told that some other matters were presented and discussed, which, however, are not considered advisable for publication.

All these entirely practical tendencies of the Naval Board contradict flatly any apprehension which the ill-informed might have as to the vagaries of what they supposed to be a board of "long-haired inventors"—long-headed would be a more suitable definition.

Program of Meeting for Presentation of Perkin Medal to Dr. Baekeland

The presentation of the Perkin Medal to Dr. L. H. Baekeland will take place on Jan. 21, at a meeting of the Society of Chemical Industry in joint session with the American Chemical Society and American Electrochemical Society. The meeting will be held in Rumford Hall, Chemists' Club, at 8 p. m. The program includes the presentation speech, which will be made by Dr. C. F. Chandler, and the speech of acceptance by Dr. Baekeland.

The Western Metallurgical Field

The Everson Flotation Patents

Renewed public interest in the contributions of Carrie J. Everson to the process of concentration by flotation has been aroused by investigations started by the Colorado Scientific Society with a view to ascertaining her whereabouts and the incidents that led to her inventions. The Everson patents, issued to Carrie J. Everson of Chicago, Ill., (348,157, Aug. 24, 1886) and to Charles B. Hebron and Carrie J. Everson of Denver, Col., (471,174, March 22, 1892) disclose not merely the essentials of flotation as practised to-day, but enter into refinements of the process that show an unusually complete investigation.

In one section of the specifications, for example, it is stated that: "The essential feature of the method which constitutes my invention, therefore, consists in commingling with pulverized ore a fat or an oil, either animal, mineral or vegetable, or a fatty constituent or acid of an animal or vegetable fat or oil, or any constituent of a mineral oil, together with an acid, either mineral or vegetable, or a soluble neutral or acid salt, for the purpose of effecting a union of the free metal or metallic portion of the ore with such admixed material, whereby the same may be retained in the subsequent separation of the quartz or other rock, therefrom by washing or other suitable means."

Among the ores on which the inventor had successfully operated, are listed those containing native gold and silver, cerargyrite, argentite, argentiferous galena and a variety of double sulphides of silver, with copper, arsenic, antimony and other base metals. Pyrite containing gold and silver, and tellurides of gold and silver also were treated. Among the oils used are specified petroleum, paraffin oil, tallow, lard, lard oil, red oil (impure oleic acid), cotton-seed oil, castor oil, sperm and linseed oils. The list of acids includes sulphuric, hydrochloric, nitric, phosphoric, acetic, oxalic, tannic and gallic. The following salts also were used: sulphates and chlorides of sodium, zinc and copper and the double sulphate of potash and alumina.

Here is an unusually broad disclosure of factors which subsequent experience has proved essential to success, either when used singly or in combination. The ores mentioned are such as are treated to-day; the oils are similar, and, of course, the acids are practically the same as now used when deemed necessary. The mention of certain salts, such as sodium, zinc and copper sulphates and chlorides, is significant of the extent to which the research was carried, for it has been observed by later investigators that salts in solution are almost essential to good work. Practically pure water has been found a poor medium in which to work, and the addition of copper sulphate has, in a number of cases, proved the saving factor.

The investigation of the Colorado Scientific Society into the early history of the Everson patents was undertaken with a view to commemorating what now appears to have been a remarkable piece of research on the part of a Colorado woman; to establish the historical facts with accuracy and to prove or disprove, if possible, the legendary reports of the inception of the process. Up to date the following facts have been established with certainty: that Mrs. Carrie J. Everson was the wife of a physician, and for many years a resident of Denver, where she engaged in charitable work as a nurse. She was not a Denver school teacher and had no brother who was a Denver assayer.

The last few years of her life were spent in California, where she died at the age of 73, Nov. 3, 1914, at San Anselmo.

New Smelter Construction

Since 1907 the Coeur d'Alene district of Idaho has been second to Missouri in lead production in the United States; but in spite of the large quantity of ore and concentrate produced, none of the output has been smelted locally. The product has been shipped to smelters in Colorado, Utah and other States for reduction. It now appears that the Bunker Hill & Sullivan Mining & Concentrating Company is to erect a smelter in the Coeur d'Alene district, possibly near Kellogg, for the treatment of its own output and that of other mines in the district. The definite location of the plant has not yet been settled, but plans are in the hands of Jules LaBarthe, of Bradley, Bruff & LaBarthe, of San Francisco, and it is expected that definite announcement of location will soon be made. The establishment of this smelter is expected to prove of great value to the lead-mining industry of Idaho, and the outcome of the venture will be watched with interest.

Other Coeur d'Alene companies have interested themselves in the purchase and rehabilitation of the smelter at Northport, Wash., and this plant is expected to be in operation early in 1916. The Tamarack & Custer and Hercules companies are represented in the new Northport Smelting & Refining Company, of which J. J. Day is president, E. R. Day secretary-treasurer, and Edward Boyce, E. R. Knight and F. M. Rothrock directors. The plant is to be equipped for both lead and copper smelting. Lead ores will be received from the mining companies directly interested in the smelter, and custom ores from other companies in the Coeur d'Alenes. A supply of copper ore is now being arranged for in the Chewelah district.

Fields Flotation Process at Ohio Copper Mill

It is announced that the Fields flotation process is to be tried experimentally at the mill of the Ohio Copper Company, near Salt Lake City, Utah. Some months ago arrangements were made for a test of this process at the Ohio mill, but the company became involved in financial difficulties which deferred action in the matter. The process is one developed by John D. Fields at the Royal Basin property, Maxville, Mont., and is conducted in an electrolytic cell. Electrolysis is said to produce two results: the generation of gas to buoy the oiled sulphide minerals, and the deposition of copper dissolved by the action of acid on oxidized minerals which may be present in the ore. The work of installing the 25-ton experimental unit is in charge of Lee M. Walton, representing the Fields company.

Activity in the Joplin District

In no section of the country have the high prices for zinc and lead had a more marked effect than in the Joplin district of Missouri. Early in November the valuation of zinc and lead produced in 1915 was in excess of \$20,000,000, or more than \$2,000,000 greater than for 1912, the previous banner year. With the output for November and December to be added to the production to date, the total valuation for 1915 will approximate \$24,000,000. The production of blende is forecasted at 250,000 tons, calamine 18,000 and galena 42,000. For the week ended Nov. 14, the base price paid for blende concentrate containing 60 per cent zinc ranged from \$85 to \$110. For the corresponding week of 1914 the range was \$40 to \$44. Calamine has been in strong demand at \$65 to \$75, basis of 40 per cent zinc, as compared with \$19 to \$21 a year ago. Galena ranged from \$60 to \$64, basis of 80 per cent lead, compared with \$42 at a corresponding period in 1914.

These conditions have stimulated mill construction which has proceeded at an unprecedented rate, both for

the treatment of old tailings and ore from new development. In the Cartersville district a 300-ton mill has been built on the Old Century and Herald mines; a 150-ton tailing mill on the land of the South Cartersville Mining Company; a 300-ton mill by the Ben Franklin company; a 250-ton mill for the Queen Esther company. The mill of the Twin Cities company has been remodeled.

At Galena a 750-ton tailing mill has been built on the Squires land; and the Grand Tower Mining Company has given a contract for the construction of a 150-ton mill on the Campbell land.

The Kusa smelter is a new plant in Oklahoma which will treat Joplin ore.

Arizona Copper Company's Fire Loss

The troubles of the Arizona Copper Company, due to labor difficulties since September, were augmented on the fifth of November by the destruction by fire of parts of the concentrating plant at Clifton. The loss is estimated variously at from a quarter to a half million dollars. As soon as the fire was discovered in No. 2 concentrator it was fought by the local fire department and men on strike. Before it was controlled the flames had destroyed No. 3 department also, and was checked only by the use of dynamite. Union sympathizers state that the fire was due to defective wiring, but this is not accepted by the company officials. It is reported that new plants will be erected as soon as labor troubles are settled.

Company Reports

In the annual report of the Nevada Wonder Mining Company is contained the résumé of operations by the Churchill Milling Company, which treats Nevada Wonder ore. The mill made a record during the year ended Sept. 30, 1915, treating 58,124 tons of ore, an average of 159.2 tons per day, and an increase of 26.1 tons per day over the preceding year. Based on actual running time, the stamps showed a tonnage of 18.01 per stamp per twenty-four hours. Gold recovery was 95.3 per cent and silver 93.68 per cent. Direct milling cost was \$2.268 per ton; indirect, \$0.545; total cost, \$2.813 per ton. Cost of power per ton was \$0.394; supplies, \$1.166; labor, \$0.705.

The Granby Cons. Mining, Smelting & Power Company, Ltd., smelted 1,098,020 dry tons of ore at its Grand Forks and Anyox plants in British Columbia during the year ended June 30, 1915. Of this amount only 24,583 tons was foreign ore. The production was 26,638,912 lb. refined copper, 377,881 oz. fine silver and 31,388 oz. fine gold. The cost of Granby copper was 10.66 cents per pound. Conditions at the new Anyox plant have improved as operations have proceeded. New charge cars have modified the feeding and distribution of the ore in the furnaces so that less trouble is experienced from crusts in the shafts. A new furnace, No. 4, and an agglomerating plant have been added to the equipment. Due to the erratic silica content of the ores received it has been impossible to operate on the semi-pyritic basis as contemplated, with low coke and little flux; but with the development of the company's own ore bodies it is expected that conditions can be more closely controlled. It is expected that the making of converter grade of matte in the first smelting will finally be accomplished. At Grand Forks the plant was closed from Aug. 7 to Dec. 7, 1914, and has since been put in full operation. Operations at this plant are on a well established basis and few difficulties are encountered. The cost of smelting was \$1.187 per ton, as against \$1.214 for 1913.

The average percentage of coke used per ton of ore was 13.17.

Baltimore Meeting of American Institute of Chemical Engineers

The eighth annual meeting of the American Institute of Chemical Engineers will be held in Baltimore, Md., from Wednesday to Saturday, Jan. 12 to 15, 1916.

On Wednesday, Jan. 12, the annual business meeting will be held at 10 a. m., at the Emerson Hotel, followed at 11 a. m. by the reading and discussion of the following two papers:

The Development of the Manufacture in the United States of Products Derived from Coal, by H. W. Jordan.

The Cracking of Petroleum and Other Hydrocarbons as a Chemical Engineering Problem, by W. F. Rittman.

In the evening of Wednesday, at 8 p. m., a meeting will be held at Johns Hopkins University, when the following three papers will be presented:

Ethyl Alcohol from Wood Waste, by A. D. Little.

The Production of Ammonia from Cyanamid, by W. S. Landis.

The Barium Industry, by M. Toch.

On Friday, Jan. 14, after a business meeting, at 9 a. m., a professional meeting will be held at 10 a. m., at the Emerson Hotel for the reading and discussion of the following papers:

A New Process of Bleaching, by S. F. Peckham.

Lutes and Cements for Chemical Purposes, by S. S. Sadtler.

On the evening of Friday, a joint meeting will be held with the Baltimore Section of the American Chemical Society at Johns Hopkins University, when Mr. Powell, of the Baltimore County Water Co., will discuss ozone purification of water and Dr. H. E. Ives will read a paper on artificial daylight.

On the evening of Thursday, a subscription dinner will be held at 8 p. m., at the Emerson Hotel. On the evening of Friday, a smoker will be tendered at the Johns Hopkins Club by the Maryland Section of the American Chemical Society.

The following excursions have been arranged:

For Wednesday afternoon, to the sewage disposal plant of the City of Baltimore and the ozone water purification plant of the Baltimore County Water Co., or to the plant of the Maryland Steel Co. at Sparrow's Point.

For Thursday (all day), to Emerson Drug Co. (bromo seltzer manufacturers) and to the Naval Academy in Annapolis.

For Friday afternoon, to the Maryland Glass Company and Crown Cork and Seal Company or to the Standard Fertilizer Works.

For Saturday, to McCall's Ferry Power Plant of the Pennsylvania Water & Power Co. or to the Tidewater Portland Cement Co., at Union Bridge, Md.

Members will be welcome at the chemical and physical laboratories of Johns Hopkins University any day during the meeting between 9 a. m. and 5 p. m.

The local committee consists of Messrs. Richard K. Meade, J. G. Dailey and W. T. Van Horn, while Dr. E. Emmet Reid represents the Maryland Section of the American Chemical Society on the committees.

Prof. J. C. Olsen, Cooper Union, New York City, is secretary of the American Institute of Chemical Engineers.

Coal in the United States.—The recently issued annual report of the Geological Survey for 1914 on the production of coal contains an interesting chart of the yearly production of coal from 1807, the date of the first discovery, to 1914.

Thermal Reactions in the Vapor Phase of Various Coal Tar Oils and Distillates*

BY WALTER F. RITTMAN AND GUSTAV EGLOFF

Previous experiments of the present general series have indicated clearly the direction and mechanism of thermal reaction among hydrocarbons. It has been shown¹ that paraffin hydrocarbons tend to form: (1) other paraffin hydrocarbons of smaller molecular weight, (2) unsaturated aliphatic hydrocarbons, and (3) aromatic hydrocarbons of mono- and poly-cyclic series. It has been shown also that inter-aromatic reactions may be arranged in a definite and consistent series. Mono-cyclic compounds with aliphatic side chains tend to form benzene, and benzene is decomposed by heat into naphthalene, anthracene and other poly-cyclic compounds.

A study² of the relative content of aromatic hydrocarbons of cracked petroleum mixtures led to conclusions of the same sort. It appeared that toluene and xylene were the products of less strenuous conditions of cracking than benzene, and it appeared also that naphthalene and anthracene were the results of the decomposition of the mono-cyclic compounds. In all the work it was indicated in a definite manner that the reactions are practically irreversible. For instance, no appreciable quantity of benzene is formed by the heating of naphthalene.

SCOPE OF THE PRESENT WORK

The present experiments were conducted for the purpose of testing the utility of various low-grade coal tar oils and distillates as original material for the production of the valuable hydrocarbons, toluene and benzene. On the basis of indications furnished by the results of previous work, it appears that transformations may be effected advantageously with such mixtures as contain mono-cyclic compounds with aliphatic side chains. The higher boiling distillates of the light oil cut, containing such hydrocarbons as xylenes, ethyl benzene, mesitylene, and cymene, would appear the most promising material possible, since the change involves only the simple splitting of a side chain attached to an exceedingly stable cyclic nucleus. On the other hand, products which consist chiefly of compounds with poly-cyclic nuclei would not seem to be utilizable, since the results of all previous experiments have indicated that the simpler hydrocarbons cannot be produced by the breaking down of the more complex aromatic compounds.

EXPERIMENTAL

The method of procedure was, in general, the same as that which has been adopted for all the series of experiments on vapor phase reactions of hydrocarbons. Details of operation were identical with those of the experiments³ in which pure aromatics were used as original materials. The oils were run through an electrically heated cracking furnace, and the resulting products collected and studied. The yields of solid, liquid and gaseous products were measured and the liquids analyzed. The latter were distilled with Hempel fractionating columns and cuts made at 75 deg., 100 deg., 125 deg., 150 deg., and thereafter at intervals of 50 deg. Specific gravities of the recovered oils and of the distillation cuts were measured. The fractions coming over at higher temperatures were examined for the presence of naphthalene and anthracene by the

simple method of chilling and noting the appearance of solid matter frozen out.

OILS USED AS ORIGINAL MATERIAL

The oils used as original material were all coal-derived products and were either of medium or of low cost. Their properties are indicated by the following descriptions:

Solvent Naphtha was a hydrocarbon mixture of slightly higher boiling point than the benzene and toluene fractions of coal tar and probably consisted chiefly of xylenes and cymene. It usually sells for a low price and is used as a solvent; but is now in such demand that it is moderately expensive, although still much cheaper than benzene and toluene. The sample used in the present experiments was obtained from a large company specializing in the working up of coal-tar products.

Creosote Oil was the ordinary product sold under that name. The sample employed in the present experiments was obtained from a second company handling coal-tar products.

Light Dead Oil was one of the typical low grade coal-tar fractions. It was obtained from the second company mentioned.

Naphthalene Wash Oil was the drip oil which comes from the presses used in separating naphthalene. It was obtained from the company furnishing the two preceding oils.

Imperial Varnish Oil was similar in properties to the solvent naphtha but was slightly heavier than the product usually sold under the latter name. The sample was obtained from a company operating in Canada.

Heavy Dead Oil was slightly heavier than the light dead oil, but contained a larger percentage of constituents boiling below 200 deg. C. It was obtained from the company furnishing the solvent naphtha.

Light Tar Oil was an intermediate product between the solvent naphtha and the creosote oil. It was similar in properties to the light dead oil.

Secondary Oil Residue was a product obtained from a steel company which operates its own by-product coke ovens. The oil was the residue left after a distillation of the product obtained by the primary fractionation of the saturated wash oil coming from the gas scrubbers.

GENERAL RESULTS OF EXPERIMENTS

Results of the present series of experiments appear in Table I. It will be noted that the sets of experiments performed for the various oils were irregular. This is accounted for by the fact that it was not considered necessary to study systematically the effects of temperature and pressure. In several cases the number of experiments performed with a single oil was limited by the size of the sample. In most cases conditions of temperature and pressure were selected which had been indicated by previous general experience as most favorable for cracking the oils in question. A few runs sufficed to yield positive results with some products, while with others, when results were of a negative nature, the ranges of temperature and pressure were more extensive. In all cases the results obtained were entirely in accord with what was expected from theoretical considerations and from the indications of previous experience.

The figures in Table I represent the specific gravities, percentage recoveries, and quantities of carbon formed, as well as the composition of the recovered oils. Distillation cut figures are given in terms of the original oil rather than on the basis of recovered oil. This in all cases reduces the apparent magnitude of the yields of benzene and toluene.

*Published with the permission of the Director of the Bureau of Mines.

¹Rittman, Byron, and Egloff—*Jour. of Ind. and Eng. Chem.*, 7 (Dec., 1915), 1019.

²Results about to be published.

³Rittman, Byron, and Egloff, loc. cit.

TABLE I—RESULTS OF CRACKING VARIOUS COAL TAR OILS AND DISTILLATES BY THE VAPOR PHASE METHOD. FIGURES SHOWING PERCENTAGE RECOVERIES, SPECIFIC GRAVITIES AND DISTILLATION CUTS OF LIQUID PRODUCTS, AND PERCENTAGES OF CARBON FORMATION

Oil Temp., deg. C Pressure, atmosphere Per cent recovered Specific gravity Per cent carbon	Solvent Naphtha							Creosote Oil						
	Original Oil	600	650	700	600	650	550	Original Oil	550	600	650	600	650	
	78.3	1	52.5	31.7	70.8	35.8	73.3	93.3	80.0	50.0	75.0	1.033	1.060	
	Tar	0.5	3.5	2.6	18.0	1.9	1.095	1.095	1.090	1.093	1.033	1.060	3.0	
Distillation cut (on basis of original oil):														
75 deg.-100 deg.	1.2	868	4.5	865	3.1	868	7.7	876	9.9	874	12.5	867	2.3	862
100 deg.-125 deg.	1.5	868	7.8	871	13.9	875	5.2	868	19.3	846	5.7	869	9.5	868
125 deg.-150 deg.	70.5	804	44.6	874	21.0	873	5.8	866	23.0	845	10.0	877	44.7	869
150 deg.-200 deg.	6.7	864	—	—	—	—	—	—	—	—	—	—	—	—
Naphthalene	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Anthracene	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Oil Temp., deg. C Pressure, atmosphere Per cent recovered Specific gravity Per cent carbon	Original Oil	600	650	700	650	700	600	700	600	650	750	650	750	
	87.0	1	86.0	62.0	63.1	45.0	70.3	35.0	67.0	43.0	33.0	1.014	1.020	
	1.007	1.022	1.048	1.060	1.040	1.028	1.015	1.028	1.014	1.040	1.020	25.2	—	
Distillation cut (on basis of original oil):														
75 deg.-100 deg.	0.9	—	1.5	—	0.5	—	2.5	875	0.9	874	2.1	879	1.0	878
100 deg.-125 deg.	1.0	—	876	1.5	—	1.1	852	1.3	875	0.9	—	880	0.7	884
125 deg.-150 deg.	4.0	860	2.6	—	3.3	—	2.2	878	1.3	—	1.9	—	1.4	885
150 deg.-200 deg.	5.5	945	—	—	—	—	—	—	—	—	—	—	—	—
Naphthalene	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Anthracene	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Oil Temp., deg. C Pressure, atmosphere Per cent recovered Specific gravity Per cent carbon	Original Oil	550	600	650	550	600	650	550	600	650	700	650	700	
	81.7	1	71.7	40.0	70.8	51.7	29.2	45.8	42.0	42.0	70.8	66.7	33.3	
	988	1.010	1.025	1.045	1.036	1.022	1.028	1.032	1.032	1.032	929	926	970	
	—	—	3.3	1.3	8.8	26.8	2.0	14.9	—	—	1.3	10.7	—	
Distillation cut (on basis of original oil):														
75 deg.-100 deg.	0.5	1.6	822	2.1	856	1.8	870	1.8	844	4.4	868	2.8	874	
100 deg.-125 deg.	2.2	878	1.9	850	1.5	868	1.6	869	3.0	874	3.2	858	4.0	
125 deg.-150 deg.	2.2	878	4.2	878	5.1	875	5.1	878	5.9	874	3.2	872	2.2	
150 deg.-200 deg.	23.0	947	—	—	—	—	—	—	—	—	—	—	—	
Naphthalene	—	—	—	—	—	—	—	—	—	—	—	—	—	
Anthracene	—	—	—	—	—	—	—	—	—	—	—	—	—	
Oil Temp., deg. C Pressure, atmosphere Per cent recovered Specific gravity Per cent carbon	Original Oil	650	700	Original Oil	550	600	650	600	650	650	700	650	700	
	66.0	1	64.0	95.0	87.5	82.5	75.8	47.5	47.5	47.5	74.0	55.0	66.7	
	1.010	1.033	1.045	964	996	1.013	983	992	979	983	1.050	981	983	
	—	—	—	—	—	—	—	—	—	—	—	—	—	
Distillation cut (on basis of original oil):														
75 deg.-100 deg.	1.6	880	2.8	876	2.5	879	6.7	857	6.7	849	7.6	869	10.3	
100 deg.-125 deg.	0.3	—	1.3	882	1.0	883	7.5	865	10.3	864	10.2	875	8.2	
125 deg.-150 deg.	0.5	—	3.3	900	2.9	903	10.3	873	7.8	876	6.2	881	6.8	
150 deg.-200 deg.	28.0	983	—	—	—	—	—	—	—	—	—	—	—	
Naphthalene	—	—	—	—	—	—	—	—	—	—	—	—	—	
Anthracene	—	—	—	—	—	—	—	—	—	—	—	—	—	

TABLE II—SECTION A. PERCENTAGE RECOVERIES OF LIQUID REACTION PRODUCTS WHEN COAL-TAR OILS ARE CRACKED UNDER VARIOUS CONDITIONS BY THE VAPOR PHASE METHOD

Temp., deg. C.	550	600	650	700	550	600	650	700	550	600	650	700
Pressure, atmosphere	1	1	1	1	1	1	1	1	1	1	1	1
Solvent naphtha	73.3	52.5	21.7	70.8	35.8	35.8	35.8	35.8	35.8	35.8	35.8	35.8
Creosote oil	93.3	80.0	50.0	62.0	63.1	45.0	70.3	35.0	67.0	43.0	33.0	33.0
Light dead oil	81.7	71.7	40.0	70.8	51.7	29.2	45.8	42.0	42.0	42.0	42.0	42.0
Naphthalene wash oil	—	—	—	—	—	—	—	—	—	—	—	—
Imperial varnish oil	—	—	—	—	—	—	—	—	—	—	—	—
Heavy dead oil	95.0	87.5	66.0	64.0	95.0	87.5	82.5	75.8	47.5	47.5	47.5	47.5
Light tar oil	—	—	—	—	—	—	—	—	—	—	—	—
Secondary oil residue	—	—	—	—	—	—	—	—	—	—	—	—

SECTION B. PERCENTAGE RECOVERIES WHEN PETROLEUM IS CRACKED BY THE VAPOR PHASE METHOD

Temp., deg. C.	600	600	600	600
Pressure, atmosphere	1	1	1	1
Pennsylvania	59.9	31.4	43.6	40.5
California	46.6	43.9	52.5	33.7

Distillation cuts are in terms of original oil, the values given being obtained by multiplying the actual distillation figure obtained by the percentage recovery.

The volume of original oil used in each run was 560 cc.

Pressures are given in approximate atmospheres. The actual pressures were atmospheric and 100 pounds, 150 pounds, 175 pounds, and 200 pounds above atmospheric. The latter four pressures are approximately 8, 11, 13, and 15 atmospheres.

MAGNITUDE OF PERCENTAGE RECOVERY

In Table II are given the figures for percentage recoveries, these being collected from Table I. The first point to be noted is that these values are considerably greater than those for recoveries from petroleum cracked under approximately similar conditions. A few figures are given, taken from the results of a previous set of experiments.¹ California and Pennsylvania oils were selected as representative of different classes. The observation that coal-tar oils are less extensively

decomposed than petroleum is exactly what would be expected, since the former are the products of a primary thermal decomposition at high temperature.

It may be observed also that there are more or less characteristic variations among the different coal-tar oils, which, however, on account of the irregularity of the series it is not possible to indicate by averages. The general tendency is toward greater decomposition on the part of those oils which have larger percentages of mono-cyclic constituents (indicated by the magnitude and specific gravity of the cut distilling below 200 deg. C.).

¹Rittman, Jour. of Ind. and Eng. Chem., 7 (1915), 945.

SPECIFIC GRAVITY OF RECOVERED OILS AND PERCENTAGES OF CARBON FORMATION

No points of particular interest are brought out by the figures for specific gravities of recovered oils and percentages of carbon formation. These values have not, therefore, been retabulated. The one observation which may be made is that neither the changes in specific gravity, due to cracking, nor the percentages of carbon formed, are as great as in cases when petroleum was the original material. This is again in accord with what would be expected when consideration is given to the fact that the coal-tar oils are the products of a primary thermal decomposition at high temperature.

FORMATION OF BENZENE AND TOLUENE

The essential point concerning which information has been sought in the present experiments is the degree of formation of the commercially valuable hydrocarbons, benzene and toluene. Since the products are not contaminated with any considerable quantities of aliphatic hydrocarbons their degrees of formation may be represented by the magnitude of the respective distillation cuts, 75–100 deg. and 100–125 deg. In the present case the amount of original oil distilling up to 200 deg may, likewise, be taken as representative of its content of mono-cyclic aromatics. The figure 200 deg. is not strictly accurate and a temperature of 15 deg. to 20 deg. lower would be better; but, as no cuts were made at this point, it cannot be used as a limit of separation. It has seemed that there ought to be an approximate relation between the amounts of benzene and toluene formed and the percentage of mono-cyclic aromatics in the original oil. That such a relation exists is indicated by the figures collected in Table III.

The following values appear:

Column I.—Percentage of benzene cut, on basis of original oil.

Column II.—Percentage of toluene cut, on basis of original oil.

Column III.—Sum of percentages of benzene and toluene cuts.

Column IV.—Percentage of original oil distilling below 200 deg. C.

Column V.—Ratio representing the degree of transformation of the 200 deg. C. original cut into benzene and toluene. This figure is obtained by dividing the value in Column III by that in Column IV.

Column VI.—Conditions of temperature and pressure under which the oils were cracked in the runs for which figures are given.

The figures are in all cases for optimum runs; those being selected which gave maximum total yields of benzene and toluene. With one exception the figures in Column V are of the same order. They indicate that the quantity of benzene and toluene formed cannot exceed the content of the original oil of mono-cyclic hydrocarbons and that the degree of formation seems to have

a maximum limit of about 50 per cent. The figures obtained would undoubtedly agree even more closely than they do if it were not for the necessary inaccuracies of assumption and of experimental manipulation. The case of the creosote oil is difficult to explain on the basis of any of the more probable causes of inaccuracy, but as it deals with a small 200-deg. cut and a small quantity of benzene and toluene formed it does not seem of great importance.

In general, it appears that by cracking under optimum conditions somewhere between 20 and 40 per cent of the portion of the original oil distilling below 200 deg. C. may be converted into benzene and toluene. The figure probably may be in extreme cases as low as 10 per cent or as high as 50 per cent.

While the indications of Table III are only qualitative and approximate, they are still of great value in determining the utility of coal tar distillates for transformation into benzene and toluene. Products like the creosote oil and the light dead oil are unquestionably useless as raw material for this purpose. Products like the solvent naphtha and varnish oil are the best possible material, although their use may be restricted on account of the factor of cost.

SUMMARY

Several coal-tar oils and distillates, all of the class less valuable commercially, have been subjected to cracking by the vapor phase method. Conditions of temperature and pressure have been chosen which seemed particularly adapted to the oils in question.

It appeared that percentage recoveries were high, as compared with those obtained when runs were made with petroleum as original material. Changes in specific gravity of liquid product and degrees of carbon formation are likewise lower than in the case of petroleum. These results were expected in consideration of the fact that the coal-tar products have once before been subjected to high temperature and brought at least approximately to equilibrium.

Oils and distillates having a considerable percentage of constituents distilling below 200 deg. C. yield large quantities of benzene and toluene, the yield being generally between 20 and 40 per cent of the 200 deg. cut from the original oil. Oils having minor percentages of constituents distilling below 200 deg. yield the same proportion of the desired hydrocarbons, but as this is likewise a small quantity they are undesirable material for transformation.

The failure to obtain benzene and toluene in such quantities as to indicate that hydrocarbons boiling above 200 deg. have been transformed is in accord with previously obtained results.*

These demonstrated that inter-aromatic reactions are irreversible, and that they proceed in the order indicated by the following series:

*Rittman, Byron, and Egloff, loc. cit. Rittman and Twomey, loc. cit.

TABLE III.—BENZENE AND TOLUENE FORMATION, AS INFLUENCED BY CONTENT OF MONO-CYCLIC AROMATICS OF ORIGINAL OIL. RATIO BETWEEN AMOUNT DISTILLING UP TO 200 DEG. IN ORIGINAL OIL AND THE SUM OF THE BENZENE AND TOLUENE CUTS

Column No. I	II		III	IV	V	VI	
	Benzene	Toluene	Benzene and Toluene	200 Deg. Orig. Distillate	Ratio Between III and IV	CONDITIONS OF CRACKING	
						Temp., Deg. C.	Pressure, Atm.
Solvent naphtha	9.9	19.5	29.4	79.9	.37	600	8
Creosote oil, . . .	2.6	1.9	4.5	2.5	1.8	600	11
Light dead oil, . . .	2.7	1.7	4.4	9.5	.46	700	15
Naphthalene wash oil	4.1	3.3	7.4	25.7	.29	600	8
Imperial varnish oil	6.8	10.7	17.5	64.5	.27	650	8
Heavy dead oil . .	2.8	1.3	4.1	30.4	.13	650	1
Light tar oil, . . .	10.3	8.2	18.5	51.8	.36	650	1
Secondary oil residue	5.7	2.2	7.9	49.4	.16	650	11

Higher benzene homologues, lower benzene homologues, benzene, naphthalene, anthracene, etc.

The only aromatic hydrocarbons capable of transformation into benzene and toluene are the higher benzene homologues, and these in general have boiling points of 175 deg. C. and below.

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Experiments on the Separation of Vanadium from Crude Sodium Uranate*

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In the extraction of radium from carnotite ore considerable quantities of uranium and vanadium compounds are obtained as by-products. When the uranium is separated by precipitation as sodium diuranate, $\text{Na}_2\text{U}_2\text{O}_7$, from solutions also containing compounds of vanadium a crude uranate of sodium is obtained, generally bearing from 5 to 10 per cent vanadium, expressed as the pentoxide, V_2O_5 . Our experiments constitute a study of several laboratory methods for the separation of vanadium in the crude uranate, and the conversion of the uranate into uranium oxide.

Since sodium vanadate is very soluble in water and sodium uranate is not, we would expect that the vanadium could be completely separated from the vanadium bearing uranate by solution of the latter in one of the mineral acids, and precipitation of the uranium by the addition of sodium hydroxide in excess. This operation does remove about one-half of the vanadium, but the yellow uranate of sodium still contains too high a percentage of vanadium for market demands. To reduce the percentage of vanadium pentoxide to less than one-half of 1 per cent by this method would evidently require four to five repetitions. Our experiments were directed toward finding a more direct method of removing the vanadium.

The stock supply of crude uranate used in these experiments was furnished by the National Radium Institute through the courtesy of Mr. R. B. Moore, physical chemist of the U. S. Bureau of Mines, in charge of the radium investigations at Denver. Several pounds of this material were ground and sampled. An analysis was made by following, in the main, the directions given in Bulletin No. 70, U. S. Bureau of Mines, page 88, for the analysis of carnotite ores. The results of the analysis are summarized in Table I.

TABLE I.—ANALYSIS OF CRUDE URANATE—PERCENTAGES

Constituent	Sample No. 1	Sample No. 2	Average
Water at 120 deg	2.91	3.33	3.12
Water of constitution	7.03	6.40	6.72
Insoluble residue	0.28	0.31	0.29
Copper and tin group oxides	0.23	0.37	0.30
Calcium oxide, barium oxide and ferric oxide	5.96	6.01	6.00
Uranium oxide (U_2O_7)	64.26	65.90	64.63
Vanadium oxide (V_2O_5)	8.60	8.50	8.55
Sodium (metal)	7.90	8.33	8.12
Total			97.73

The apparently low total is due to the fact that for every three molecules of sodium diuranate, $\text{Na}_2\text{U}_2\text{O}_7$, there are five atoms of oxygen which are not accounted for in the above results. If we calculate the amount of oxygen to be added, assuming that the crude uranate contains 64.63 per cent of the oxide, U_2O_7 , the per cent of oxygen not accounted for would amount to 3.07 and the total percentage then is 100.8.

Working on a laboratory scale, we have succeeded

in reducing the vanadium content of the crude uranate to less than one-half of 1 per cent by several methods: (1) Removal of the vanadium as a volatile product by treatment with hydrochloric acid gas. (2) Treatment with ammonium chloride. (3) Separation of vanadium by treatment with some of the common mineral acids.

Treatment of the Crude Uranate with Hydrogen Chloride

Edgar F. Smith and Joseph B. Hibbs¹ first showed that vanadic acid can be completely removed from sodium vanadate as a volatile product by means of hydrochloric acid gas. Later, it was shown by Hillebrand that a part of the vanadium in ores, the vanadous compounds, are not completely removed by this method. Our first experiments were undertaken to ascertain whether the vanadium in the crude uranate can be volatilized by hydrogen chloride. The crude uranate was subjected to the action of hydrochloric acid under varying conditions of temperature. It was found that crude sodium uranate which had been ignited in the free flame to remove moisture present, and then subjected to dry hydrogen chloride evolves brown fumes characteristic of the chlorides and oxychlorides of vanadium. The reaction proceeds fully as well at room temperatures as when the uranate is heated. Evidently the reaction produces enough heat to raise the temperature sufficiently to volatilize the chlorides and oxychlorides of vanadium.

During the process a slight caking is produced as a result of the water formed in the reaction, and this sometimes prevents the hydrogen chloride from interacting with the vanadium in the interior of the uranate. In such cases it is necessary to heat the uranate residue to a temperature high enough to expel all the moisture present, then to grind it to a fine consistency. When hydrogen chloride is passed over it a second time a slight evolution of brown fumes is again observed, showing that only traces of the vanadium are left. Two treatments with hydrogen chloride gave a very complete quantitative separation of the vanadium.

The residue left after the separation of vanadium probably is a mixture of sodium chloride, sodium uranate, and uranyl chloride. This residue is readily soluble in dilute acids, from which the uranium can be obtained in the form of oxides by either precipitation with ammonia and ignition of the uranate, or else by boiling with ammonium chloride, which likewise converts the major part of the sodium uranate into ammonium uranate.

In subjecting the vanadium bearing uranate to the action of hydrogen chloride, the uranate was placed in a long, hard-glass tube of 1-cm. bore. One end of the tube was fitted with a one-hole stopper, carrying a glass tube. A steady stream of hydrogen chloride was passed over the uranate in the tube and maintained until the evolution of the brown fumes ceased. The reaction was carried out at different temperatures by placing the glass tubes in a combustion furnace and regulating the temperature.

In order to get some idea of the quantitative separation of the vanadium from the crude uranate by this method, the volatile compounds of vanadium from a weighed sample of uranate were absorbed in water. The aqueous solution of vanadium was oxidized with hydrogen peroxide, and evaporated nearly to dryness with sulphuric acid. It was taken up with water and reduced with sulphur dioxide. The solution was then boiled to expel the excess of sulphur dioxide, after which the hot solution was titrated with a standard solution of potassium permanganate. The amount of

*Extract of a thesis submitted by Howard H. Barker in the Graduate School of the University of Missouri in partial fulfillment for the degree of Master of Arts, June, 1915.

¹Jour. Am. Chem. Soc. 16, 578 (1894).

vanadium in the aqueous solution was found to vary from 8 to 8.2 per cent of V_2O_5 , as against 8.55, the amount actually found in the crude uranate by analysis. This result shows that the vanadium is nearly removed quantitatively. The residue showed only a feeble test for vanadium.

Whether this method can be conducted on a commercial scale is an open question. In designing a large form of apparatus, a chemical engineer must consider the following points: (1) The material to be used in the construction of the apparatus, wood, metal or stone-ware. (2) The process should be made continuous. That is, all the hydrogen chloride should be utilized by passing that which is rich in the products of the reaction over fresh crude uranate. (3) The water formed during the reaction is sometimes very objectionable, as it produces caking. The apparatus should, therefore, have a stirring device. (4) Some provision should be made for collecting the volatile vanadium compounds. (5) An efficient hydrogen chloride generator is an important part of the apparatus.

After removal of the vanadium by this method, the next step is the conversion of the uranium compounds into urano-uranic oxide (U_3O_8). One of the commercial methods of conversion consists in boiling the sodium uranate with a concentrated solution of ammonium chloride. Ammonium uranate is produced, but the conversion is not complete. Upon ignition, the ammonium uranate is decomposed, yielding uranium oxide. A mixture of uranium oxide and sodium uranate is thus obtained, from which the sodium uranate is removed by digesting with dilute sulphuric or hydrochloric acids. From 10 to 15 per cent of the uranium oxide, however, is also dissolved. Hence the recovery of uranium oxide is only partial.

In this connection some experiments were conducted on the conversion of sodium uranate into uranium oxide. In one series of experiments both dry and moist samples of pure sodium uranate were dissolved in a slight excess of concentrated sulphuric acid and then precipitated with an excess of ammonia. After ignition and extraction with dilute sulphuric acid 59 per cent of the uranium was recovered as pure oxide U_3O_8 , and in the case of moist uranate, the recovery was 64 per cent. This process resolves itself into virtually treating the sodium uranate with ammonium sulphate. Another experiment consisted in boiling both dry and moist sodium uranate in concentrated solutions of ammonium chloride, filtering off the precipitates, igniting and treating the residue with dilute sulphuric acid.

In the experiments with the dry sodium uranate by this method, the recovery of uranium oxide was found to be 64 per cent, and in the case of moist sodium uranate, a recovery of 61 per cent was obtained. These experiments show that in one of the commercial methods of converting sodium uranate into oxide approximately 64 per cent of the uranium is recovered, and assuming that 15 per cent of the uranium oxide is dissolved by the acid used in extracting the sodium uranate, it is seen that 75 per cent of the sodium uranate is converted into ammonium uranate.

Treatment of Carnotite Ore with Hydrogen Chloride to Remove Vanadium

Since hydrogen chloride removes vanadium completely from crude sodium uranate, the idea suggested itself of trying the effect of the gas on the vanadium in the original ore, with a view of developing a quantitative method of determining the vanadium in carnotite ores.

A few charges were run at room temperature, but it was found that the removal of the vanadium was far from complete, thus confirming the conclusions of Hille-

brand.² Experiments were next tried by heating the ore while the hydrogen chloride was passing over it. It was found that the yield of chlorides and oxychlorides was much greater, but even in this case, only about one-half of the vanadium was removed. The ore caked rather badly, due to the water formed in the first part of the operation, so it was necessary to remove it from the tube, pulverize it and treat it again with hydrogen chloride.

The experiments which yielded the best results were conducted as follows: the sample of the ore was placed between plugs of glass wool in a hard-glass tube and hydrogen chloride passed over it until no more brown fumes were given off. The hydrogen chloride generator was disconnected then and the ore heated to drive off all moisture present. After this it was removed from the tube, thoroughly ground and mixed with powdered glass in order to let the gas have an opportunity to come in direct contact with each particle of the ore. The sample was replaced in the tube and hydrogen chloride (gas) passed over it for about two and one-half hours, at as high a temperature as could be obtained in the combustion furnace. The residue that remained in the tube was brown and sandy-like in appearance and gave only a very slight test for vanadium. Other experiments conducted under nearly the same conditions failed to give as satisfactory results as the one above did, showing that it is rather difficult to remove the vanadium by this method.

The treatment of the ore by hydrogen chloride for the removal of vanadium has a very direct bearing on the problem at hand. If the vanadium could be removed from the ore by this treatment at the beginning of the process a uranate would be obtained free from vanadium. Moreover, the removal of the vanadium before treatment of the ore for the extraction of radium would very materially simplify the entire process.

Treatment of the Crude Uranate with Chlorine Gas

In connection with the experiments of hydrogen chloride for the removal of vanadium, chlorine gas suggested itself as a possibility. Experiments were tried substituting chlorine gas for hydrogen chloride, but the results were negative. Chlorine gas does not react with the vanadium present in the crude sodium uranate, and only a minute trace of the tetrachloride and oxychloride of vanadium was observed.

Separation of Vanadium by Means of Ammonium Chloride

Inasmuch as hydrogen chloride readily removes vanadium from crude sodium uranate as a volatile product, it seemed worth while to conduct some experiments with mixtures of ammonium chloride and sodium uranate at somewhat elevated temperatures. Under these conditions the partial dissociation of ammonium chloride into ammonia and hydrogen chloride would furnish the constituent to react with the vanadium, and at the same time the ammonia and excess of ammonium chloride furnished favorable conditions for the conversion of some of the uranate into the oxide.

A number of preliminary experiments were conducted to ascertain: (1) quantity of water to have present in the mixture of uranate and ammonium chloride, (2) the temperature at which the reaction should proceed, (3) the amount of ammonium chloride required, (4) the kind of a vessel best adapted for the experiments, (5) the effect of other ammonium salts when added as partial substitutes for ammonium chloride.

Experiments were first conducted by mixing the crude uranate and dry ammonium chloride and subjecting this

²Bulletin No. 70, U. S. Bureau of Mines, 82 (1913).

mixture to heat in a test tube. The ammonium chloride was readily volatilized but apparently no vanadium was volatilized. A part of the uranate, however, was converted into the oxide. Experiments were then tried with the mixtures of ammonium chloride and crude uranate made up to a thick paste by the addition of water. When the paste is subjected to heat the water is gradually expelled, and then as the temperature is increased copious fumes of ammonium chloride are given off, and just as the volume of chloride vapor diminishes the characteristic brown vapors of the volatile vanadium compounds make their appearance and continue to be evolved copiously until the molten mass in the crucible becomes solid. Upon testing the residue obtained in this treatment, it was found to contain only a trace of vanadium.

The experiment was here tried of pouring the molten liquid from the crucible into a beaker containing water, to ascertain whether mere fusion with ammonium chloride would render the vanadium soluble. The melt dissolves almost completely in the water. The solution has a decided green color and gave test for both uranium and vanadium. Evidently this procedure must be included in the list of negative experiments.

Experiments were next conducted to determine the minimum quantity of ammonium chloride required for the nearly complete separation of vanadium by the above procedure. Mixtures of uranate and ammonium chloride in the following proportions were heated: (1) ten parts by weight of ammonium chloride to ten parts by weight of crude uranate, (2) fifteen parts by weight of ammonium chloride to ten parts by weight of crude uranate, (3) twenty parts by weight of ammonium chloride to ten parts by weight of crude uranate. The vanadium was satisfactorily separated only in the case where twice as much ammonium chloride was used as crude sodium uranate.

The experiments were first conducted in iron crucibles, but it was noted that a crucible would not stand more than two charges before it showed holes. Nickel crucibles were attacked fully as badly. Iron test tubes made out of 1½-in. steam pipe capped at one end only withstood two charges. Alundum and porcelain crucibles, however, served the purpose very well, and in the experiments that follow porcelain crucibles were used.

In a few experiments, ammonium nitrate was substituted for a part of the ammonium chloride usually used. This modification did not yield very satisfactory results. While it was possible to remove the vanadium by using a mixture of fifteen grams of ammonium chloride, five grams of ammonium nitrate and ten grams of sodium uranate, the percentage conversion of uranium into oxide in the residue was thereby reduced, as shown in the tabulated data that follow.

As a result of these preliminary experiments the following procedure was adopted: A known weight of sodium uranate, ten grams in most cases, was taken and twice that weight of ammonium chloride added. The mixture is placed in a mortar and pulverized, which at the same time mixes it. The pulverized mixture is then placed in a porcelain crucible and water added until a stiff paste is obtained. Heat is then applied slowly at first with constant stirring to drive off the excess of moisture. Strong fumes of ammonia are noted at this point. As the mass becomes dry it has a tendency to cake, but with vigorous stirring this can be prevented to a large extent. After the water has been expelled the mass begins to fuse and continues to do so until there is a green molten liquid in the crucible. This liquid boils freely with the expulsion of ammonium chloride fumes until the excess of ammonium chloride is driven off and then the brown fumes of the chloride and oxy-

chloride of vanadium begin to make their appearance. They were given off very copiously toward the end of process and especially as the molten mass became solid. Sometimes these brown fumes make their appearance before solidification begins, but usually not. As soon as the volatile products cease to be given off, the crucibles were removed from the flame because further heating of the residue greatly increases the percentage of sodium uranate in the residue.

The black residue from this treatment gives a slight test for vanadium. The percentage of vanadium may be estimated colorimetrically by comparison with standard solutions of vanadium. In this way it was found that the vanadium content of the uranate is reduced from 8.55 per cent vanadium oxide to less than 0.5 per cent.

To ascertain to what extent the uranium is converted into the oxide by treatment with ammonium chloride, several quantitative experiments were conducted. The weight of the residue after treatment with ammonium chloride was first determined by introducing the ammonium chloride and a weighed quantity of uranate mixture in a tared crucible and making a run. From the weight of the residue thus obtained, the ratio of residue to uranate was found to be 0.958.

To ascertain the percentage conversion and the percentage of recovery of uranium, analyses were made of the residues obtained in several experiments. The residue from the crude uranate obtained by treatment with ammonium chloride must consist of a mixture of uranium oxide, sodium uranate, sodium chloride, iron oxide and impurities from the ammonium chloride. This residue was shaken with dilute (1:40) sulphuric acid in excess, which dissolves out the sodium salts of uranium and chlorides, and a small percentage of uranium oxide, leaving a black residue consisting of uranium oxide with a small amount of iron oxide. For commercial use the iron present is usually not objectionable.

Table II shows the results of a quantitative determination made on a portion of the residue, obtained by treating a given weight of crude uranate with twice its weight of ammonium chloride to determine the percentage of recovery of uranium oxide and the percentage conversion.

Column 2 represents the weight of the residue taken from a charge and used for analysis. Column 3 represents the equivalent weight of crude uranate calculated from the ratio 0.958. Considering the crude uranate contains 64.6 (Table I) per cent uranium oxide, the values in column 4 are deduced and represent the total amount of uranium oxide present in the residue. Column 5-a represents the weight of uranium oxide found after treating the residue with dilute (1:40) sulphuric acid. However, it was found, as will be shown later, that this residue is only 95 per cent pure, and thus b represents the weight of uranium oxide actually recovered on this basis. Column 6 represents the amount of uranium oxide present in the residue before treatment with dilute sulphuric acid. Assuming that 15 per cent of the uranium dissolved in the dilute acid used to remove the remaining sodium uranate. Column 7 repre-

TABLE II—RECOVERY OF URANIUM OXIDE

No. of Sample	Weight of Residue	Crude Uranate Equivalent	Total U ₃ O ₈ as Oxide	Weight of Pure U ₃ O ₈	Total Conversion	Per Cent Recovery	Per Cent Conversion
1	0.5918	0.6184	0.3995	a—0.2840 b—0.2692	0.3174	67.4	79.2
2	0.6082	0.6355	0.4105	a—0.2930 b—0.2778	0.3268	67.6	79.6

sents the percentage recovery, figured from the weight or uranium oxide given in b, column 5. Column 8 represents the percentage conversion based upon the values of column 6.

The purity of the uranium oxide removed was determined by dissolving two samples of the uranium oxide residue after treatment with dilute sulphuric acid in nitric acid. The insoluble material was filtered off, and the iron precipitated with ammonium carbonate in excess. The iron was filtered off and the ammonium carbonate solution boiled to expel the excess of ammonia and precipitate the uranium compound, which was then converted to uranium oxide by ignition. In this way it was found that the residue contained 94.8 per cent U_3O_8 .

To ascertain the effect of temperature on the percentage recovery of uranium, an experiment was run in which the final temperature was raised much higher than in the preceding case. Only 58 per cent of uranium oxide was recovered and the conversion was reduced from 79.5 to 68.3 per cent.

To confirm this conclusion a third series of experiments was conducted in which the volatile products were vaporized at still lower temperatures than obtained in the first experiment. The recovery of uranium oxide was raised to 78.5 per cent and the conversion attained the value 92.4 per cent. Hence the lowest temperature possible to remove the vanadium gives the most efficient recovery of uranium oxide.

A quantitative determination was made on the residue obtained by treating ten grams of crude uranate with a mixture of fifteen grams of ammonium chloride and five grams of ammonium nitrate. The vanadium here was removed to less than half a per cent, but the results of the experiment clearly showed that the percentage recovery, 48.8 per cent of uranium oxide, is very materially decreased. While the addition of the ammonium nitrate reduces somewhat the temperature at which the mixture fuses, it is evident its presence materially reduces the yield of uranium oxide.

Separation of Vanadium by Means of Mineral Acids

A—NITRIC ACID

Hillebrand refers¹ to the work of Friedel and Cumenge² on the separation of vanadic acid from carnotite ore by rendering the oxide insoluble in water by evaporating the nitric acid solution to dryness. This method of separating the vanadium from crude sodium uranate was tried, but it did not work very successfully, as a large part of the uranium was rendered insoluble as well as the vanadium, and then, too, the vanadium was not completely removed from the uranate.

Some modifications of this method were then tried, which finally furnished a quantitative method of separating vanadium from the crude uranate. In connection with some qualitative experiments upon the action of nitric acid on sodium uranate, we found that when the vanadium bearing uranate was dissolved in dilute nitric acid and the solution then boiled that the vanadium was precipitated quantitatively.

Quantitative experiments were then conducted to determine the following factors: (1) the proper amount of nitric acid necessary to dissolve the crude uranate, (2) the recovery of uranium from the solution of uranium oxide and its purity, (3) the amount of uranium in the precipitate containing the vanadium.

1. *The Quantity of Nitric Acid.*—By taking weighed samples of uranate and dissolving them in nitric acid of different concentrations and then boiling this solu-

tion to precipitate the vanadium, it was found that acids ranging in concentration from N/20 to N/50 completely removed the vanadium. Boiling of concentrated nitric acid solutions of the uranate results in only partial precipitation of the vanadium. The quality of pure nitric acid necessary for a given weight of crude uranate is given in the table below. It might be stated here that it is only necessary to boil the nitric acid solution for two or three minutes to precipitate the vanadium. It should also be stated that the quantity of nitric acid required is practically that shown by the equation,



2. *Recovery of Uranium and Its Purity.*—The recovery of the uranium from the filtrate of the nitric acid solution is best accomplished by precipitating it with ammonium hydroxide and then igniting the precipitate of ammonium uranate. Some sodium uranate is probably precipitated out with the ammonium uranate, which, upon ignition gives a mixture of uranium oxide and sodium uranate along with a small quantity of iron. The sodium uranate can be easily removed by agitating the ignited residue with cold dilute (1:40) sulphuric acid. The oxide of uranium thus obtained is free from vanadium, and sodium uranate.

It was found on analysis of the uranium oxide obtained after treatment with dilute sulphuric acid that it was about 95 per cent pure. The impurity here is undoubtedly due largely to iron present, which is not objectionable for most commercial purposes.

3. *Uranium Present in Precipitate Containing Vanadium.*—The amount of uranium present in the vanadium precipitate was determined in a manner similar to that used in determining the uranium in carnotite ore except that dilute hydrochloric was used to dissolve the precipitate. Concentrated hydrochloric acid and aqua regia do not dissolve it completely. The analytical data obtained are summarized in Table III. The uranium content given in column 3 was deduced from the analysis given in Table I. Column 4 gives the weight of insoluble residue containing the separated vanadium and the next column shows the weight of uranium oxide present in the residue. The figures in the last column show that about 14 per cent of the uranium is carried down in the residue. The further treatment of this residue for the separation of uranium and vanadium is in progress.

TABLE III.—ANALYSIS OF VANADIUM PRECIPITATE

No. of Sample	Weight of Crude Uranate	Total U as Oxide	Weight of V_2O_5 Residue	Weight of U_3O_8 in Residue	Per Cent U_3O_8 in Residue	Per Cent U_3O_8 of Total U_3O_8
1	2.8270	1.826	0.5728	0.2506	43.7	13.2
2	2.9383	1.898	0.5590	0.2733	48.9	14.4

Next a series of determinations was run to find the weight of pure nitric acid required to react with a given weight of crude uranate, the percentage recovery of uranium oxide and the weight of the vanadium residue. Four determinations were made and the results obtained are given in Table IV. The numbers in the fifth column represent the weights of crude uranium oxide recovered and the next column gives the weights of uranium oxide after treatment with dilute sulphuric acid to dissolve out sodium uranate.

It will be noted from this table that the recovery of uranium dropped considerable in the cases of samples 2 and 4. This result is readily accounted for when the sulphuric acid filtrate (column 6) was taken and analyzed for uranium oxide. In the case of sample 2, 22.5

¹Bulletin 262, U. S. Geological Survey—Contributions to Mineralogy, 22.
²Compt. rend. 125, 532 (1899).

TABLE IV

Number of Charge	Weight of Crude Uranate	Total U as Oxide	Weight of Pure HNO_3 per G. of Uranate	Weight of U_3O_8 by Pp't	Weight of U_3O_8 Obtained After Treatment with Dilute H_2SO_4	Weight of V_2O_5 Residue
1	3 6197	2 3383		2 1320	1 8530	
2	2 8270	1 8262	0 6048	1 5986	1 0534	0 5728
3	2 9383	1 8940	0 5738	1 0472	1 2097	0 5590
4	10 5883	6 8440	0 5719	5 9026	4 0116	2 2349
					Per Cent V_2O_5 Residue	Per Cent U_3O_8 Recovered
1						79.2
2					20.2	56.6
3					19.0	65.4
4					21.1	58.6

per cent of the total uranium oxide was found in the filtrate and 25 per cent for sample 4. It will also be noted that the weight of vanadium residue bears an almost uniform ratio to the weight of the crude uranate treated. This method of treatment still leaves approximately 13.5 per cent of the total uranium in combination with the vanadium, but the vanadium is completely removed and 65 per cent of the uranium is recovered as pure oxide.

B—TREATMENT WITH HYDROCHLORIC AND SULPHURIC ACIDS

After obtaining a good separation of vanadium from crude uranate with dilute nitric acid, the investigation was extended to dilute hydrochloric and sulphuric acids. Experiments were conducted very similar to those used in the case of nitric acid, and it was found that here, again, the vanadium could be removed quantitatively with hydrochloric acid, but only in some experiments was the treatment with sulphuric acid successful.

Two samples of the crude uranate of approximately five grams were dissolved in the least possible amount of hydrochloric acid, which had been standardized. The solutions were then brought to a boil and boiled for a few minutes to precipitate the vanadium which settled out very readily. The vanadium residue was filtered off and ammonia added to precipitate the uranium. The precipitate of ammonium uranate was filtered off, ignited to uranium oxide and the residue treated with dilute (1:40) sulphuric acid to extract the sodium uranate present in the ignited residue.

Table V gives a summary of the results obtained in these experiments.

TABLE V SEPARATION OF VANADIUM WITH HYDROCHLORIC ACID

Number of Charges	Weight of Crude Uranate	Total U as Oxide	Weight of Pure HCl per G. of Uranate	Weight of U_3O_8 by Pp't	Weight of U_3O_8 in H_2SO_4 Residue	Weight of U_3O_8 in Filtrate	Weight of V_2O_5 Residue
1	5 7852	3 7383	0 3492	3 3586	2 3864	0 8884	1 0360
2	5 4948	3 5496	0 3712	3 2353	2 4673	0 7078	1 4530
		Per Cent		Per Cent	Per Cent	Per Cent	Per Cent
1		64.63		80.8	63.3	23.8	18.4
2		61.63		91.1	69.5	19.9	22.7

Comparing the percentage of vanadium oxide residues here obtained with those obtained by the nitric acid treatment, it appears that the percentage weight of the vanadium bearing residues averages 20.5 per cent, which is in good agreement with the percentage obtained by the nitric acid treatment. Hence we as-

sume that the vanadium oxide residue is the same in both cases.

It will also be seen, from the table, that the percentage of pure uranium oxide in sample 2 is greater than in sample 1, but, on the other hand, the amount of uranium oxide recovered from the sulphuric acid treatment is less, which accounts for the difference. It thus appears that the two acids serve equally well.

A number of experiments have been conducted with sulphuric acid of different concentrations ranging from fifth normal to fortieth normal following the same procedure as with dilute nitric and hydrochloric acids. Thus far we have met with but partial success. In a few instances out of a number of trials the characteristic brown vanadium bearing precipitate was obtained, and the separation of vanadium was practically complete. The quantity of uranium in the precipitate was found to be practically the same as in the precipitate obtained by treatment with nitric acid.

More frequently, however, when the dilute solution of sodium uranate was boiled a canary yellow precipitate appeared. The quantitative experiments conducted made it evident that a part of the vanadium remains in solution whenever the canary yellow precipitate comes down. If we can succeed in duplicating some of the quantitative results obtained in a few cases the treatment with sulphuric acid would be ideal as the cost of sulphuric acid is considerably less.

Summary of Results

The experiments here described have resulted in at least four methods that have proved successful for removal of vanadium from the crude uranate, which is obtained on a large scale in the plant of the National Radium Institute.

1. By the action of hydrogen chloride gas it has been shown that in time the vanadium is completely removed, leaving a residue consisting of sodium uranate, sodium chloride, uranyl chloride, and the other impurities in the crude uranate.

The uranium may be removed from this residue by either of two methods: (1) By boiling with excess of ammonium chloride, which converts the uranium into ammonium uranate, which may be ignited to uranium oxide; (2) by dissolving the residue in a dilute mineral acid and precipitating the uranium with ammonia, as ammonium uranate, which may be converted into uranium oxide by ignition.

The percentage recovery of uranium oxide, free from vanadium, but containing a small percentage of iron, which is not objectionable for its sale, varies from 59 to 64 per cent.

2. By mixing the vanadium bearing uranate with twice its weight of ammonium chloride and enough water to make a thick paste, the vanadium may be nearly completely volatilized by heating in a porcelain crucible. When subjected to proper conditions of temperature, it is possible to reduce the quantity of vanadium present in the crude uranate from 8.5 per cent to less than $\frac{1}{2}$ of 1 per cent. The ammonium chloride serves the double purpose of converting a part of the uranium present to ammonium uranate, which, upon ignition, yields uranium oxide as well as removing the vanadium.

The percentage of uranium recovered may be regulated very materially by the heat treatment to which the mixture is subjected. Where the residue, after volatilization of the ammonium chloride, is heated to a high temperature, the percentage recovery of the uranium oxide (U_3O_8) is reduced due to the fact that some of the uranium oxide formed in the operation is converted back to sodium uranate.

The highest percentage recovery was obtained where the temperature was not raised any higher than necessary to volatilize the ammonium chloride and vanadium compounds.

In this connection it was found that a mixture of fifteen grams of ammonium chloride and five grams of ammonium nitrate to every ten grams of crude uranate served the purpose of removing the vanadium from the crude uranate just as well as the ammonium chloride alone. However, the percentage recovery of uranium oxide is reduced very materially, as it is only possible to get a recovery of about 58 per cent under the most favorable conditions of temperature. This reduction in the percentage recovery more than counterbalances any advantage that the use of ammonium nitrate might have as a partial substitute for ammonium chloride.

3. The vanadium can be completely precipitated by dissolving the crude uranate in the least possible amount of dilute nitric, hydrochloric and sometimes sulphuric acid, and then boiling the solution. Approximately 13 per cent of the uranium is precipitated out with the vanadium, but the amount is small compared to that which remains in solution. The uranium may be recovered by adding ammonia to the solution containing the uranium, free from vanadium, to precipitate it as ammonium uranate, which may be converted into uranium oxide by ignition.

The percentage recovery of uranium oxide in the case of nitric and hydrochloric acid treatments is found to vary from 58 to 79 per cent. Some uranium is lost in the dilute sulphuric acid treatment of the residue for the removal of the sodium uranate, but this uranium may be recovered from the acid solution by precipitation with ammonia.

Only by one of the above methods is the removal of the vanadium and the conversion of the uranium oxide accomplished in one step. That is the case of the ammonium chloride treatment. In all of the other processes the vanadium is removed by one step and the uranium recovered by another operation. However, it will be noted that the percentage recovery of uranium oxide in all the methods was practically the same.

4. Probably hydrogen chloride (gas) may also be utilized to remove the vanadium from carnotite ores quantitatively, by proper regulation of temperature.

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The American Smelting & Refining Company's tin-smelting plant in the course of construction at Perth Amboy, N. J., will shortly be finished. The company will receive concentrates from Bolivia by way of the Panama Canal, smelt these in reverberatory furnaces with subsequent electrolytic refining. Some shipments of ore have been held up at the canal, which have delayed operations. Very pure tin analyzing 99.95 per cent has been produced in the experimental plant and it is the intention to make a tin to compete with Straits tin.

Geological Survey Cannot Make Assays.—The United States Geological Survey calls the attention of mining men and others to the fact that it is not equipped for making assays or analyses of rocks, its laboratory being in fact overloaded with official work. Many specimens and samples are received by the Survey, accompanied by requests for such treatment, with which it is impossible to comply. The force of chemists employed is small, and their time is fully occupied by their regular official duties. The Geological Survey has no facilities for making gold and silver assays. The most the Survey geologists can do is to give an off-hand opinion based on a simple examination of the specimens.

The Rubber Industry

BY ANDREW H. KING

It has been said that too frequent association dulls the appreciation and relegates important discoveries and advances to the rank of the commonplace. This statement holds very true about rubber. The most of us have grown up with rubber articles about us all our lives. In fact, our association with this remarkable substance dates from the nursing bottle. Consequently, it is not at all out of the way for us to accept rubber as a matter of course.

No material has yet been found which combines such a degree of strength, elasticity, and wearing power. These properties make rubber especially valuable in manufacturing the various grades of hose—air, water, steam, and oil; belts; valves and other molded articles, and tires of all kinds. A complete list of all the various things made of rubber would be almost infinite.

The first mention of this remarkable substance from a European was by Christopher Columbus, who on his second voyage of discovery (1493-1496) saw the natives of Haiti playing with balls, which he afterward learned were prepared from the gum of a tree. This gum they called *cauchu*, from which the word *caoutchouc* is derived. Highly interesting must this gum have been to the Spaniards. By it they were able, in a crude manner, to waterproof their garments, and thus protect themselves from the heavy tropical rains. They also made the acquaintance of the related substance, *balata*. They found shields made of *balata* impregnated cloth. The same material was used in the preparation of suits which resisted poisoned arrows. In fact, such suits are now to be seen in the Spanish museum at Madrid. This was indeed a fine forerunner of the modern *balata* belt.

The English word rubber was given it by Priestly in 1770, who recommended its use for removing pencil marks. This would likely have remained its principal use had not the discovery of vulcanization been made. Raw rubber is not suitable for proofing garments, due to the narrow range of temperature within which it is elastic but not sticky. Below 10 deg. C. it begins to become hard, and at 0 deg. C. it is brittle. However, it regains its former properties on warming. Above 25 deg. C. it has a great tendency to become sticky, and if heated above 75 deg. C. it becomes permanently tacky.

But in 1839 Nelson Goodyear, an American, made his important discovery of vulcanization. The beginning of the rubber industry dates from this invention. The bicycle craze of some years ago gave it added impetus, and as the cycle went out automobiles came in. It is now an accepted fact that these machines cannot be comfortable without pneumatic tires. It has been estimated that at least 85 per cent of all rubber used in manufacturing goes to tires, and only 15 per cent to mechanical goods. The United States alone uses about 100,000 tons of crude rubber per year. So we see that rubber is an established industry.

The Varieties of Crude Rubber

Schidrowitz divides the important rubber-producing trees into four orders, with the following subdivisions:

- | | |
|-------------------|------------------|
| I. Euphorbiaceae— | 3. Clitandra. |
| 1. Hevea. | 4. Hancoria. |
| 2. Manihot. | 5. Dyera. |
| 3. Sapium. | III. Urticaceae— |
| 4. Micandras. | 1. Ficus. |
| II. Apocynaceae— | 2. Castilleja. |
| 1. Funtumia. | IV. Compositae— |
| 2. Landolphia. | 1. Guayule. |

Hevea, brasiliensis.—This is by far the most important rubber of the whole family. It supplies over 60



FIG. 1—HALF HERRING-BONE SYSTEM

per cent of the total output. It was originally native to South America, where great forests of these trees abound. They are often of great height and girth. From the experience planters have had with Hevea in the East, the age of these trees must be well over 500 years. For these reasons alone they should produce the best grade of rubber. In addition, the method of curing or coagulating the latex, while very primitive, gives a product far superior to that secured from cultivated trees. The Amazon valley is the principal rubber district of South America. Commercial Brazilian rubbers are usually classified as Up-river or Hilands, and Islands. The former is shipped from Manaos, which is about a thousand miles up the Amazon. The latter comes from the City of Para, on the coast. Hilands is sometimes called hard cure and Islands soft cure. The commercial varieties include also Fine Para, Coarse Para, Caucho, Matto Grosso, Peruvian, and Bolivian.

The Hevea brasiliensis has been transplanted to the East Indies. Climatic and soil conditions proved suitable, and the wild rubber tree has yielded to cultivation. Now great quantities of rubber are produced on such islands as Ceylon, Borneo, Sumatra, and on the Malay Peninsula. Many varieties of plantation sheets are on the market.

Manihot glaziovii.—This variety is native to Brazil, but has been planted with success in parts of Africa, where Hevea brasiliensis proved a failure. The most important commercial variety of the species is Ceara or Manicoba.

Funtumia elastica.—This species is native to tropical Africa, and supplies the rubbers known as Gold Coast Lumps, and some of the Congo and Cameroonian varieties.

Landolphia, ovariensis, etc.—These species include various vines and creepers which occur in enormous quantities in Congo and parts of the East and West Coast, and in Central Africa. The vines are ordinarily cut down and the latex secured by bleeding. It furnishes Upper Congo balls, Sierra Lione Niggers, Red and Black Kassai, and Madagascars.

Hancoria speciosa.—This species is native to Brazil



FIG. 2—HERRING-BONE SYSTEM

and central South America. It yields Mangabeira, Pahia, and Matto Grosso.

Dyera costulata.—This supplies the very poor rubbers known as Pontinak, Jelutong or Dead Borneo. They contain but about 15 per cent of rubber, the remainder being resin, dirt and water. This variety comes from parts of the Malay Peninsula, Sumatra, and Borneo. Considerable quantities of it are purified. The resin finds many uses, and is sold under the name Malaysian or Pontinak resin. Formerly the trees were felled and bled where they lay on the ground. This very wasteful method has almost entirely given place to scientific tapping. The rubber extracted from Ponti is very good.

Ficus elastica.—This species is found principally in Asia. Burmah, Java and India are the important districts. It has been planted to some extent in the Dutch and German African colonies.

Castillai elastica.—This variety is indigenous to Mexico, Central America and Peru. It produces Peruvian Caucho, Mexican Strips and Centrals.

Parthenium argentatum.—From this species is obtained Guayule. It is found principally in Mexico and southern Texas. The rubber occurs in the solid state among the woody fibers of the shrub. Guayule found considerable favor in this country until continued revolutions made the gathering of the shrub and the extraction of the rubber at least rather hazardous, if not to say impossible. While the production of Guayule destroys the shrub, it does not seriously cripple the industry, since it grows very fast and was formerly looked upon as farmers regard blackberry bushes.

For 1912 Maclaren made the following estimate, which will serve to show the relative importance of the various grades of rubber. In these figures allowance has been made for the resin content of low-grade rubbers.

Plantations	28,500 tons
Brazil (Amazon Basin)	48,830 tons
Brazil (Bahia)	4,000 tons
Central America	2,500 tons
Africa	20,000 tons
Guayule	3,500 tons
Jelutong	6,000 tons
Total production	113,330 tons



FIG. 3—SERINGUEIRO SMOKING RUBBER AT ALTO ACRE

Basing his figures on the increase in production of plantation rubbers, the decreasing supply of some wild rubbers, and upon the further demand, he estimates for 1916 as follows:

Brazil	15,500 tons
Central America	250 tons
Africa	1,000 tons
Jelutong	500 tons
Plantations	130,000 tons
Total production	147,250 tons

While the figures for 1915 are hardly yet available, it seems that his estimate will at least prove conservative. For 1920 he estimates as follows:

Brazil	2,000 tons
Various	500 tons
Plantations	160,700 tons
Total production	163,200 tons

According to his opinion the cheaper grades of rubber will be gradually eliminated, and there will remain only Brazilian and plantation rubbers. Another factor in driving out the low-grade rubbers is the improved shoddy processes, which furnish cheap and fairly good material. In fact, many rubber chemists prefer high-grade shoddy to some of the low-grade rubbers.

The following figures were taken from an extensive table by Spence, and serve to show the relative values of crude rubbers on the basis of their washing loss and resin content.

Trade Name	Washing Loss,		Resin Content,	
	Per Cent		Per Cent	
Fine Para, Islands.....	17	-20	2	-3
Fine Para, Hilands.....	14	-19	1.6	-3
Plantation Crepe	0.2	-1	1.3	3.6
Caucho	18	-23	3.5	5.5
Manicoba	30	-55	3	6.5
Gold Coast Lump.....	30	-55	7	10
Jelutong	64	-70	70	-85
Guayule	15	-40	20	-25

Tapping

Rubber is derived by a process of coagulation from the latex of certain trees, shrubs, or plants, which have been already discussed. The latex is quite distinct from the sap, and is contained in a separate cell system which lies between the outer bark and the cambium. Obvi-

ously a very thorough knowledge of the lactiferous system is necessary to yield the best results on tapping.

In the Amazon district the old V method is still in use. It consists of a series of V's, the first being about 6 to 7 ft. above the ground, and successive cuts beneath it down the trunk. The next row begins about 18 in. over, and just a little lower than the first one, and so on down the tree. The third row begins with a cut on a level with the first one. Earthenware cups are placed at the apex of each V to collect the latex.

In the plantation districts of the East the half herring-bone method is most preferred. This consists of a series of oblique cuts running into a central channel. See Fig. 1. Additional tapping is done by paring away a strip of bark about 1/4 in. wide along each cut. When a sufficient area is exposed the tapping is transferred to the opposite quarter of the tree. When the allowable area of trunk is exposed on that side, the tree is left to rest for three or four years. Later the tapping is begun on the quarters adjacent to the former wounds. The full herring-bone method also finds favor, and consists of simply twice the area of the half herring-bone. See Fig. 2. The latex is collected in a small iron cup fixed at the base of the central channel. These cups are emptied at regular intervals, and the latex taken to the plantation factory for coagulation. There are other ways of tapping, but these are the most important.

The Nature of Rubber Latex

Latex is a white to cream-colored fluid, resembling milk in appearance. When this emulsion is examined under the ultra-microscope it is found to consist of very minute (0.5 to 4 mu.) oil-like colloidal particles floating in a clear serum. They are in rapid Brownian movement, and when the latex is electrolized they go to the positive pole, thus proving them to be negatively charged colloids.

The liquid is either slightly alkaline or amphoteric in reaction. It contains various enzymes, which if allowed time to act will produce acids, and thus precipitate the colloids. Besides India rubber, the latex contains vari-

ous resins, proteins, and acid salts, such as sulphates, malates, phosphates, and chlorides. Sugars and alkaloïds may also be present. Seelingmann gives the following average analysis of Para latex:

	Per Cent
India rubber	32
Albumenoid extracts and mineral matter	12
Water	56

Coagulation

By coagulation we mean the formation of an irreversible colloidal gel. The colloids coalesce. The particles grow larger and larger, and begin to throw out minute hair-like arms and connect one another. This leads to a reticulated or network structure which is not lost when

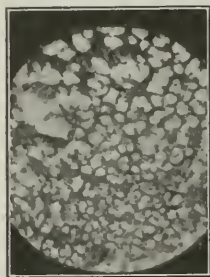


FIG. 4A — MICRO-PHOTOGRAPH OF A DROP OF FRESHLY COAGULATED FUNT. ELAS. LATEX, SHOWING RETICULAR STRUCTURE



FIG. 4B—THE SAME AS "A" AFTER APPLYING PRESSURE. NOTE THE ALTERATION IN STRUCTURE. (FROM A DRAWING.)

the sheet is ready for market. Schidrowitz coagulated a drop of latex between a slide and cover glass, and noticed that the reticulated appearance could be intensified and made coarse by working a little and by using slight pressure. Fig. 4 illustrates this phenomena. This gave him an explanation of the effect of working on freshly coagulated latex. Latex coagulated by chemical means appears first as a cheesy mass, which readily gains in strength and cohesiveness on working through the rolls.

Coagulation has been performed by many methods. In this paper I will only discuss those most in use and which give the best results. The market value of a rubber depends much on the care used during coagulation. For example, African rubbers are as a rule very dirty, highly resinous, and of a very foul odor. No care is used in gathering the latex; in fact, many of the savages smear it on their stomachs until they have a good-sized lump, and then peel it off. The heat of their bodies coagulates it.

Probably the oldest and undoubtedly the best method of coagulation is that used in the Amazon country. The "seringueiro" or rubber gatherer first makes a small fire, in which he burns the nuts of the urucuri palm. These nuts give a dense smoke, which is rich in the products of wood distillation, such as creosote, acetic acid, and so forth. Next he places a long pole or mandril over the fire, and pours on it a small quantity of latex. The pole is rotated until a thin film of dried rubber has formed, when he makes another application. The process is repeated until he has a loaf of about 100 lb. Rubber so prepared forms the biscuits of trade, which are easily recognized since the loaf is made up of concentric layers which may be separated. Fig. 3 shows the hut of the seringueiro. There is no rubber better than Hilands Fine Para. The method of coagulation is largely responsible for this, since it allows all

the elements of the latex to be evenly distributed throughout the mass.

On the plantations coagulation is brought about by the addition of a small quantity of very dilute organic acid. Acetic is mostly used, though formic also finds favor. It has become the custom to add a small quantity of sodium sulphide to the latex before coagulating. This acts as a preservative, and prevents enzyme action which would otherwise cause a black rubber. Most of the Eastern sodium sulphide rubber is sold under the name of Ceylon, and is a very nice, white, clear rubber, greatly in favor, if not absolutely essential, to the manufacturer of white articles. The requisite quantity of acid is added, and the latex allowed to stand a short time, during which coagulation occurs. The freshly prepared rubber is worked and washed on corrugated rolls. This removes any serum left in the pores, and also any foreign matter.

At this point it is well to mention that this excessive cleanliness is a detriment to plantation rubber, for it removes certain nitrogenous bodies which greatly influence the time of vulcanization, and thus make necessary the employment of some form of accelerator. Accelerators are used also with Para, but are not nearly as necessary.

After washing, the rubber is sheeted on smooth rolls. It is then dried, either by means of vacuum dryers or by hanging in a loft. When dry it may be smoked. Hardwood is mainly used for this purpose, and it supplies much the same vapors as are used along the Amazon. The object is to disinfect the rubber and thus prevent bacterial action. Rubber so treated is called smoked sheets, and forms a large portion of the plantation output.

Kaye in a recent article gives the following amounts of various acids required to coagulate normal Hevea latex containing 30 per cent of rubber:

Acid	$\frac{N}{10}$ cc. Acid to 100 cc. Latex
Sulphuric	20 cc.
Hydrochloric	9 cc.
Nitric	31 cc.
Acetic	150 cc.
Oxalic	31 cc.
Tartaric	33 cc.
Citric	71 cc.
Formic	20 cc.

He mentions the fact that no matter what acid is used for coagulation, after the process is complete there is always approximately twice the acidity in the case of Hevea latex than one should expect from the quantity of acid used. The increase is thought to be due to phosphoric acid produced by the hydrolysis of some of the protein groups.

Physical Properties of Rubber

As was previously stated, the structure of rubber is reticular. It is this property which makes possible the addition of large amounts of other substances, as is regularly done in compounding. Films of rubber prepared from solutions do not display this structure until treated with sulphur chloride, after which it is quite pronounced.

The specific gravity of clear washed and dried rubber is usually taken as 0.925. On warming, the gravity gradually decreases.

Rubber is not soluble in water, but will absorb as much as 45 to 50 per cent of it. It is insoluble in acetone or alcohol, consequently these solvents are mainly used in extracting the resinous constituents. It forms a typical colloidal solution with benzole, gasoline, chloroform, toluene, ether, etc. Fig. 5 is an ultra-microscopic photograph of a solution of rubber with benzole.

Chemical Properties

This subject is very broad, and not well established. A full discussion is beyond the scope of this paper.

Alkalies.—Neither aqueous nor alcoholic solutions of the alkalies effect it; i.e., below 100 deg. C. Prolonged digestion with ammonia causes india rubber to pass into an emulsion closely resembling the original latex.



FIG. 5—ULTRA-MICRO-PHOTOGRAPH OF A SOLUTION OF RUBBER IN BENZENE

Chlorine.—When chlorine is passed through a rubber solution a white powder having the formula $C_{10}H_{16}Cl_2$ is formed. This is evidently an addition and substitution product.

Bromine.—Bromine forms in the same manner two products, $C_{10}H_{16}Br_2$ and $C_{10}H_{14}Br_4$. The tetrabromide has been suggested as a means for the direct determination of the percentage of rubber in rubber analysis.

Acids.—Hydrochloric acid gas does not act on vulcanized rubber articles when absolutely dry. In the presence of moisture an additional product is formed.

Sulphuric acid when concentrated acts very vigorously, charring and oxidizing it.

Nitric acid, concentrated, attacks rubber energetically, forming first a yellow body which is subsequently decomposed into nitrogen, carbon dioxide, oxalic acid, and a substance of the character of a fat. On prolonged boiling this is converted into a mixture of camphoric and camphoronic acids.

Nitrous acid, when carefully prepared by running concentrated sulphuric acid into a 20 per cent solution of sodium nitrite and carefully dried by passing the gas through drying tubes containing phosphorous pentoxide, then passed into a solution of dry rubber in water-free benzene, a product having the formula $C_{10}H_{14}N_2O_4$ is formed. This is the rubber nitrosite, and is an amorphous, yellow compound which is insoluble in most of the ordinary solvents, but fairly soluble in dimethyl oxalate. This product has also been suggested for the direct determination of rubber.

Dry Distillation.—On dry distillation of purified Hevea, Weber obtained the following:

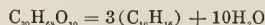
	Per Cent
Isoprene	6.2
Dipentene	4.6
Heveene	1.7
Polyterpenes	26.8
Carbon residue	1.9
Mineral residue	0.5
Loss (water and gases)	1.4

The Rubber Hydrocarbon

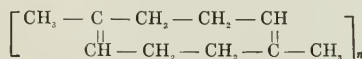
When commercial rubber is highly purified, it is found to consist almost entirely of a substance having the empirical formula $(C_5H_8)_n$ or $(C_{10}H_{16})_n$. The latter one is most accepted.

Commercial rubber also contains about $3\frac{1}{2}$ per cent of a so-called "insoluble" constituent. Before Weber's study of the subject and his determination of the correct amount, it was thought to supply the strength, while the true rubber hydrocarbon gave the elasticity. Weber easily disproved this theory, and showed it to have the formula $C_{10}H_{16}O_{10}$. He suggested that it forms a link between rubber and the complex carbohydrates, as the celluloses, which he considers the raw material from which the plant produces all the terpenes, includ-

ing rubber. He illustrates his theory by the following reaction:

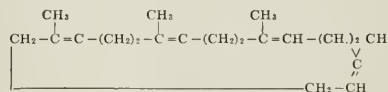


Harries, on the basis of his work on rubber ozonides, regards it as polymerized 1:5 dimethyl cyclo-octadiene



Rubbers obtained from different sources are not always identical in structure. Harries found that while ozonides of purified Hevea gave on hydrolysis mainly laevulic aldehyde and laevulic acid as a secondary product, the reverse was true of the ozonides of gutta percha, which also has the formula $(C_{10}H_{16})_n$, and of certain African species. His explanation is that the ozonide complex occupies a different position relative to the plane of the eight-ring space, a cis position in one and a trans in the other.

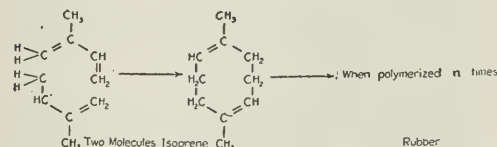
Pickels has suggested that this behavior be explained on the assumption that the rubber hydrocarbon does not consist of a number of polymerized $C_{10}H_{16}$ rings, but of a single ring containing a number of unsaturated C_5H_8 nuclei.



Synthetic Rubber

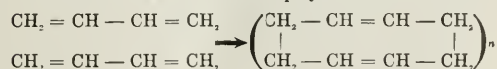
The production of synthetic rubber has long been the dream of the organic chemist. The conquest of alizarin and indigo gave him confidence to attempt this most difficult task. Synthetic rubber has already been produced, but not in quantities, nor at a price that can compete with the natural product. For synthetic rubber to be an assured success it must be cheap. It has been said that rubber can be laid down in this country from the East at 20 cents a pound should occasion demand it. The rubber grower has allied himself with the botanist, and each year he is strengthening his position. However, should cheap synthetic rubber come, we may well expect the rubber streets that have been predicted.

The beginning of the attempt to synthesize rubber dated from the researches of Harries into the nature of the rubber hydrocarbon. According to his theory, two molecules of isoprene polymerize to 1:5 dimethyl octadiene and this is further polymerized n times to rubber.

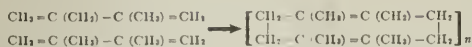


Natural rubbers seem to be derived from isoprene, but for simplicity and logic the synthetic chemist begins with butadiene, also called divinyl or vinylethylene $CH_2 = CH - CH = CH_2$, since isoprene is but B methyl butadiene $CH_2 = C(CH_3) - CH = CH_2$. One fact seems already proved. Whenever the grouping $C:C:C$ can be obtained in a compound that compound is capable of being polymerized to rubber. By making substitutions in the butadiene hydrocarbon, it should be possible to secure a whole series of rubbers.

Two molecules of butadiene polymerize as indicated:



In accordance with the above, dipropylene rubber should be formed:

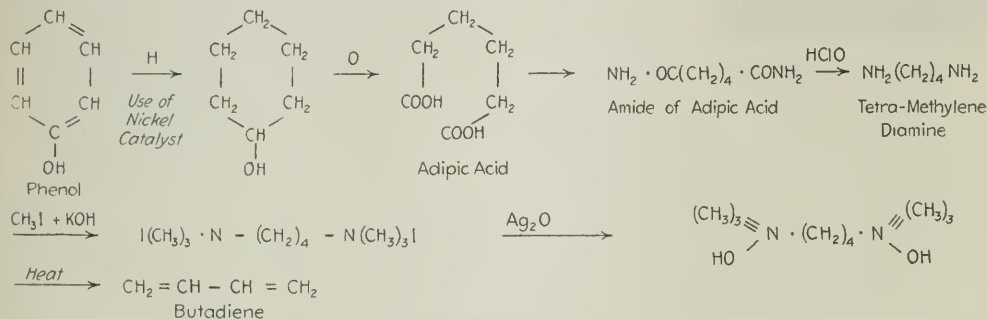


Thus we see that the first part of the problem is to make butadiene or its homologues cheaply. The second part is to efficiently polymerize this substance or substances to rubber. The solution of the second part is already nearly complete, but the first still seems difficult.

The following methods have been proposed for the production of butadiene and its homologues:

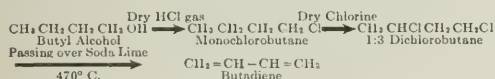
From Phenol

Hofman has used the method of synthesis outlined below. For butadiene he begins with phenol, and for isoprene he starts with paracresol. The reactions are identical, so I will indicate only those for butadiene.



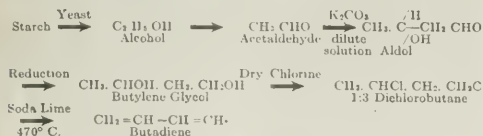
By Fermentation From Starch

Fusel Oil Route.—Fernbach has developed a form of bacteria which is capable of producing about 42 per cent of fusel oil from starch. By varying the conditions of fermentation he claims he can produce fairly large quantities of acetone as a by-product. The butyl alcohol of fusel oil is separated and purified. The steps in the process are indicated below.



By using iso-amyl alcohol, which forms a large percentage of the fusel oil obtained from cereals or potatoes, in place of butyl alcohol in the above indicated process isoprene can be obtained.

Acetaldehyde Route.—Perkin in his synthesis also begins with starch, which he ferments to ethyl alcohol by means of yeast. This is converted to acetaldehyde. From this he obtains aldol, which is converted to butadiene by the steps which are indicated below. He claims that this method, when fully developed, will produce rubber at as low as 15 cents per pound.



From Turpentine

The isoprene lamp has long been known. Harries and Gottlob prepared isoprene by its use quite early in

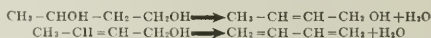
their researches. It consists of nothing more than a flask, in which is suspended just below the neck a platinum coil, which is electrically heated to incandescence. The turpentine or other liquid is boiled in the flask. The vapors are decomposed by the coil and the isoprene is separated by fractionation. Herty and Graham obtained 5.5 per cent isoprene from spirits of turpentine in this manner. By trying the different fractions of commercial spirits of turpentine, they concluded that this is mostly due to pinene and not to dipentene, as was claimed by Harries and Gottlob.

By the use of the isoprene lamp, Harries and Gottlob also obtained as high as 50 per cent isoprene from commercial limonene. Since the volatile oil of pinus serotina contains considerable limonene, Herty and Graham used it in place of turpentine in the isoprene lamp. They obtained a yield of 12 per cent isoprene.

Turpentine as a raw material is too expensive for any of these processes to be a decided success.

Pyrogenic Reactions

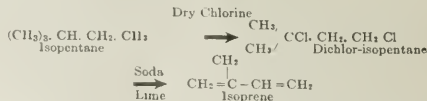
Some very excellent work has been done by Kyriakides on this side of the water. His process is essentially one of dehydration. For example, one method for the preparation of butadiene is as follows: beta-butylene glycol is slowly dropped into a tube containing pieces of ignited kaolin heated to 380-400 deg. C. Butadiene is obtained. The dehydration, he thinks, takes place thus:



The reader is referred to his original work, as published in the *Journal of the American Chemical Society*, Vol. 36, pages 530, 657, 663, 980, 987.

From Petroleum

Petroleum has been suggested as a source of butadiene, and its homologues, since by careful fractionation isopentane, $(\text{CH}_3)_2\text{CH}-\text{CH}_2\text{CH}_3$, can be obtained. This may be converted to isoprene by the following steps:



The above are the principal published methods for the production of butadiene and its homologues.

As before stated, the second part of the problem consists in efficiently polymerizing these substances to rubber.

Tilden was the first to discover that isoprene could be converted to rubber. In 1882 he examined a tube of isoprene which had been sealed and set aside twenty

years previously. He was surprised to find its contents no longer liquid. This substance he took to be rubber. It has been said that he did not sufficiently prove that his product was rubber, however there seems to be no doubt that he was right.

If isoprene is spontaneously converted to rubber as the above would indicate, then catalysers which would hasten the reaction should exist. This fact led to the trial of many substances, such as acetic anhydride, hydrochloric acid, etc. Different observers at times obtained polymerization products, but on the whole their experiments could not be satisfactorily duplicated by others.

However, in 1912 Matthews tried the action of sodium wire on isoprene, and was successful. He used about 5 per cent of sodium and kept his sealed tubes slightly warm. This discovery proved to be the key to synthetic rubber, for it provided a rapid, cheap and efficient method of polymerization.

A "seeding out" process has been developed by the chemists of the Bayer company. By it isoprene is heated in an autoclave, where spontaneous polymerization takes place. The process is said to yield a clear white rubber which can be vulcanized.

Vulcanization

By vulcanization we mean the change which takes place when rubber and sulphur are heated together, or when rubber is treated with a dilute solution of sulphur monochloride. The first is called hot vulcanizing and the latter cold curing, which is the word given to this change by rubber chemists. The early investigators of vulcanization called it simply the "change."

Hot Vulcanizing.—In 1839 Goodyear discovered that by treating mixtures of sulphur and rubber at high temperature, the range of temperature within which rubber retains its elastic and non-sticky properties was considerably increased over the crude form. He later also discovered ebonite, which is the end product of the reaction between sulphur and rubber.

Broadly speaking, normal soft vulcanized rubber contains from 2 to 4 per cent combined sulphur, that is, sulphur not extractable by solvents such as acetone. Hard rubber, or ebonite contains from 20 to 30 per cent combined sulphur. The maximum 32 per cent is seldom obtained in commercial ebonite, due to the extended length of time of heating and the large excess of sulphur necessary.

The action of sulphur with rubber seems to be partly physical and partly chemical. It is an addition process, either by adsorption or by straight chemical addition, or what is more probable, by both. It is not by substitution, as was originally thought.

The amount of sulphur which enters into combination with rubber, that is, the combined sulphur, increases with time and rise of temperature. The combination is not a linear function but shows certain jumps at more or less regular intervals. Of these jumps Weber says that they may be taken as probably indicating a particular physical rather than some definite chemical condition of the vulcanized product. His reason is that by curing at different temperatures the jumps occur at different places. Axelrod, on the basis of his experimental work, concluded that vulcanization consists of two separate processes. First, the action of heat on rubber which tends to de-polymerize it; and second, the entry of sulphur into the molecule, thus tending to increase the molecular complexity. He arrived at the conclusion that when de-polymerization due to heat has proceeded so far, the material is in favorable condition for a fresh sulphur attack, and at such points a jump occurs in the curve.

If temperature and time are kept constant, the amount of sulphur entering into the molecule is dependent on the quantity originally present. Weber noticed the fact that articles containing less than 2 to 2½ per cent combined sulphur did not appear vulcanized. Therefore, he concluded that this amount of sulphur is necessary to produce the first of a series of compounds called by him polyene sulphides. This closely approximates the formula $(C_{10}H_{16})_{10}S_2$. By using varying large amounts of sulphur he obtained ebonites which all showed approximately 32 per cent combined sulphur, which would indicate another compound with the empirical formula $C_{10}H_{16}S_2$. He concluded that there exists a whole series of vulcanized bodies, of which $(C_{10}H_{16})_{10}S_1$ is the lowest, and $C_{10}H_{16}S_2$ is the highest.

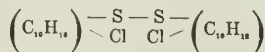
Erdmann has brought forth rather an interesting idea. At 160 deg. C., which is practically the upper limit of vulcanization temperatures, melted sulphur contains a large proportion of thiozonide, S_3 , molecules. Since thiozonide readily polymerizes to an eight-ring complex, it is highly probable that this ring would unite with another eight-ring such as rubber is supposed to be. This would give a rubber thiozonide corresponding to the well-known ozonides.

Wolfgang Ostwald has suggested that vulcanization is a physical proposition only, based on the adsorption of sulphur by the rubber colloid.

At present the consensus of opinion of American chemists seems to be that vulcanization is both a physical and chemical change, and that the adsorption of sulphur while actually taking place, is only a secondary matter.

Cold Vulcanizing.—In 1846 Alexander Parks patented the second method of securing the "change." He immersed his samples in a 2½ per cent solution of sulphur monochloride, S_2Cl_2 , in carbon bisulphide. Of late carbon tetrachloride has been used instead of carbon bisulphide with equally good results, and with far less danger. The cold vulcanizing solution is called curing acid in the trade.

The process is only applicable to articles of less than 4 mm. thickness, since before the "acid" could penetrate to the interior, the surfaces would become hard and brittle, "burnt." The cold process finds considerable favor in the vulcanizing of thin goods, such as surgical gloves, etc. It is used quite extensively in combination with rubber cement, and to some extent in curing proofed articles, such as raincoats. The compound formed by cold vulcanization is chemical, and is believed to have the formula:



A method of enameling iron, which may find application in the laboratory by reason of the simplicity of the procedure, is described by M. P. Wood in his work on Rustless Coatings. The metal is first pickled in hydrochloric acid to free it from foundry scale, then washed thoroughly and dried. The first coating applied is composed of 34 parts silica, 2 parts soda and 15 parts borax, mixed in water. The metal thus coated is exposed for 10 or 15 min. in a dull-red-hot retort. A second coating is then applied, consisting of 34 parts feldspar, 19 silica, 24 borax, 16 oxide of tin, 4 fluor-spar, 9 soda and 3 salt-peter. This mixture is first melted in a crucible, then ground to a fine paste in a little water and applied with a brush. The coated piece is then again subjected to white heat in a muffle. It is claimed that the enamel unites with the iron and that pipes thus enameled have been in use for many years without deterioration.

Hydrometallurgy of Zinc and Lead in 1915

A Contribution from the Department of Metallurgical Research, University of Utah, D. A. LYON, Metallurgist in Charge, O. C. RALSTON and J. F. CULLEN, Assistant Metallurgists

The year 1915 witnessed the installation of a great number of semi-commercial plants for the treatment of zinc ores by leaching methods, with subsequent electrolysis of the solution in order to obtain metallic zinc. Practically all of these installations have been in the nature of experimental plants.

When the European war started there were three electrolytic zinc plants in Europe supposed to be operating on a commercial scale. All of these were on a small scale, and were producing zinc from by-products. At Winnington, Northwich, Cheshire, England, was the plant of Brunner, Mond & Co., which is an alkali works and which has been disposing of calcium chloride solution wastes by leaching zinc ores with them (with simultaneous action of carbon dioxide). This gave a zinc chloride solution from which the zinc was recovered by electrolysis, giving a spelter containing 99.96 per cent Zn., and producing chlorine gas which was absorbed to make bleaching powder. This process is one of those originally designed by Hoepfner, and was experimented on during the 90s in Germany, resulting in the installation of a like plant at Duisburg, Germany. Both of these plants have kept secret the exact details of the process by which they have been able to get good zinc deposits as their pure spelter has been for years at a premium of at least 1 cent above the ordinary market price.

In 1914, a plant was built for treatment of zinc carbonate ores at Kristiania, Norway, under the direction of Borchgrevink, and another at Balestrand, Sogn, Norway, under the direction of E. A. Ashcroft, to treat flotation concentrates from Broken Hill. So far as we know, nothing has been heard of these plants since the war began.

In the United States and Canada, however, a great deal of experimental work has been done on the leaching of zinc from ores with its subsequent electrolysis. Nearly all of this work has been sulphuric acid leaching followed by the electrolysis of the zinc sulphate solution. While all the various plants have this much in common, the details of the work varies at most of them by almost as many methods as there are plants.

The Anaconda Copper Company perhaps has gotten farther along with this work than have most of the other companies. They now have a 25-ton plant nearing completion. By a 25-ton plant is meant one that will produce 25 tons of metallic zinc per day. The Anaconda metallurgists regard this as only an experimental plant. Some splendid work has been done at Anaconda in their research work in connection with the development of the process which they are using and the publication of the details of this work by Mr. Laist and his associates will be keenly awaited by those interested in this line of work.

As to the general outline of the processes employed at the various plants at Trail, B. C., and at Anaconda, the electrolytic liquor containing sulphuric acid, regenerated by electrolysis with insoluble anodes, is used for leaching the ore. The ore is a roasted complex sulphide of lead and zinc carrying silver, some gold (and some copper in the case of Anaconda). By the use of barely sufficient acid to dissolve the zinc, it is possible to get a solution of zinc sulphate carrying low amounts of the other constituents of the ore. This solution must be cleaned by the use of zinc oxide, lime or other cleaning agents, and is then electrolyzed. At most of the plants, lead anodes are used in the electrolytic

tanks in order to regenerate sulphuric acid. The process as thus outlined is old, but the refinement of detail has been the feature of nearly every plant attempting to use it.

At Murray, Utah, and Omaha, Neb., are small plants recovering zinc electrolytically. The one at Murray is following the practice as developed at Anaconda, with variations made necessary by local conditions. It is only an experimental plant and it is expected to produce about 2 tons of zinc per day. The Omaha plant is working on zinc oxide material from the refining of argentiferous lead by the Divine process, and is also in the nature of an experiment.

Perhaps the most extensive research work on the leaching and electrical precipitation of zinc has been carried out on the ores of the Bully Hill mine, Shasta County, California. The process for the Bully Hill ore was worked out on the assumption that a good deposit of zinc cannot be obtained from a solution containing much sulphuric acid and the effort has been to neutralize the acid as fast as it is formed at the lead anodes. In treating the Bully Hill ore, lime is used to precipitate zinc hydroxide and calcium sulphate from the solution of the zinc sulphate. This precipitate is suspended in the zinc sulphate liquor of the electrolytic cell and as fast as sulphuric acid forms it is neutralized by the zinc hydrate.

The Reed Zinc Company whose plant is at Palo Alto, Cal., has operated on the bag house dust from the Kennett smelter of the U. S. Smelting, Refining and Mining Company. This is also an experimental plant designed to produce about a ton of zinc per day. Instead of a solid lead anode they use a sponge lead anode resembling the electrode used in a storage cell. As fast as sulphuric acid is formed at this anode it combines with the lead, forming lead sulphate. This lead sulphate can later be used to give up the acid by reversing the current, after placing the electrode in a sulphuric acid solution. The solution for electrolysis is prepared by dissolving zinc sulphate crystallized from the leaching liquor.

At Silverton, B. C., the Standard Silver Lead Mining Company is also experimenting with the production of electrolytic zinc by the French process. French was probably the first man to use manganese in the electrolysis of zinc sulphate solutions, although its beneficial effect has been noticed by other investigators. He found that it deposits as dioxide on the anode and can be redissolved in sulphuric acid and used over again. He operates his process with considerable of the manganese sulphate in his electrolyte, and instead of using sulphuric acid for leaching, uses a solution of by-product sodium bisulphate.

At Welland, Ontario, the Weedon Mining Company is also said to be meeting with success in operating the Watts process. This process proposes the use of a solution of zinc sulphate for an electrolyte in electrolysis, the depolarization of the anode and the prevention of the formation of sulphuric acid by the use of any solid compound of zinc which does not contain objectionable impurities, such as zinc oxide, or blue powder. The fundamental idea of this process is the same as has been worked out in the treatment of the Bully Hill ore. It is also brought out in the recent patents of O. Best of Oakland, Cal.

At Mt. Read on the west coast of Tasmania, it has been reported that the Tasmanian Metals Extraction Company erected a plant for the treatment of zinc-bearing ores, producing a concentrate of zinc oxide. Nothing of the details of the process has been given out, but the zinc is doubtless precipitated from solution by a solution of some alkali, and the resulting hydrate calcined to oxide.

It is noticeable that most of these plants are treating complex ores of lead and zinc, and usually they are sulphide ores. There is a great amount of "complex sulphides" available in various mining districts and much of it has resisted all efforts at separation. Most of the lead smelters are receiving ores with a considerable zinc content and the zinc causes them to operate at a great handicap on account of the difficulty of fusing the zinky slag and due to the fact that a large amount of lead and silver is caused to go into the slag. Most of these smelters have been looking around for ways and means of removing this zinc before the ore goes into the blast furnace and there is no doubt that the removal of the zinc will allow much more economy in the lead smelting. For example, it is stated that one of the smelters in the country has concluded that even if zinc costs 7 cents per pound for removal and sells for 5 cents, the operation will still allow them latitude enough in the operation of the lead smelter to make the process slightly profitable. It is also stated that the Anaconda plant expects to produce zinc for 4 cents or even less. It is doubtful if small plants can produce zinc at such a low cost and it is also doubtful if it is possible at the present time to install a small electrolytic zinc plant which will be a paying proposition. In order to produce zinc cheaply electrolytically, extraordinarily cheap electric power is a very important item. Moreover, the plant must be comparatively large and this means that only the larger companies would at the present time be warranted in producing zinc in this manner, as this cost of installation is too great except for the large companies.

In other words, it now looks as if the production of zinc electrolytically is not a "poor man's proposition" for the reason that installation costs for a plant which will make money are liable to run well into the millions. However, as the work progresses, it may be found that this is not necessarily true.

The complex sulphides are, of course, being roasted before treatment, and it is worthy of note that most of the experimental work is being done with McDougal and Wedge furnaces. The roasting takes a considerably longer time than does the roasting in ordinary lead smelting and there is some question as to whether this type of furnace will do the work satisfactorily. Zinc smelters have used Hegeler and other like furnaces in which the time of roasting is as much as sixty hours, while most Wedge and McDougal furnaces are so constructed that the ore will travel through the furnaces in four hours, but can easily be slowed down to eight. Whether this type of roaster will meet the requirements or not is still a question.

Very little has been done with the carbonate ores which carry zinc, although it is understood that most of the smelters in Utah have experimented with the leaching of these ores. The Salt Lake station of the Bureau of Mines in connection with its work on the low-grade and complex ores has been doing work along this line and finds that most of the carbonate ores yield up their zinc readily. Very little has been done on the electrolytic deposition of the zinc in the solutions obtained by leaching these ores with sulphuric acid. The carbonate problem is not as pressing as is the mixed sulphide problem, for the reason that in most districts the sulphides constitute the main ore, and furthermore, the carbonates of lead which are found in most districts are not as seriously contaminated as are the zinc ores, for the reason that in the weathering process the lead carbonate resulting from galena does not travel far from the original galena while the zinc carbonates are often found at considerable distances from the original position of the sulphides. However, there are plenty of instances of mixed carbonates of lead and zinc that defy

treatment, and being carbonates they have been let alone whenever it was found that they were complex, due to the fact that very few instances are known where they could be mechanically separated.

All things considered, it would seem as if a very decided advance had been made in the hydrometallurgy of zinc during the year 1915 and while the total amount of metallic zinc produced to date by electrical precipitation has been small, and at present commands a premium as "brass special," it will probably not continue to do so long, due to the large amount of it which will be produced by new plants now being installed or contemplated.

Lead

The hydrometallurgy of lead has received serious consideration during the past year. Inasmuch as it is sometimes found difficult to leach copper ores at a profit, it may seem strange that any one would even consider leaching an ore for such a low-priced metal as lead. However, if we compare the atomic weights and chemical equivalents of copper and lead, it will be seen that the quantity of chemicals required to extract a pound of copper should extract $3\frac{1}{2}$ lb. of lead. Counting lead as worth 3 cents to the producer in the mountain region, the net result of the use of the chemicals which extract 1 lb. of copper will be 11 cents worth of lead. Although such a comparison looks favorable when made in this manner, the difficulty has been to find a suitable solvent for lead.

The Bureau of Mines station at Salt Lake City in its work on the recovery of lead values from the low grade lead ores made a study of the results obtained in three different mills during 1914 and found that the possibility of leaching lead was not at all discouraging. For example, at the mill of the Mines Operating Company, in Park City, the superintendent, Mr. Holt, found that his brine solutions built up to 8 lb. of lead per ton. He was giving his ore a chloridizing roast and then leaching with a 20 per cent salt solution. This was extracting the copper, gold and silver of his ore. Some of the lead precipitated on the scrap iron which was used for removal of the copper from the solution, but this was only a small part of the lead in his ore.

At the Knight-Christensen mill in Silver City, it was also noticed that lead was soluble in the brine solution and steps were being taken to recover this lead when the mill burned down. They had been very successful in recovering it on a laboratory scale by electrolysis of the solution.

The Bunker Hill and Sullivan mill at Kellogg, Idaho, had also been trying out a chloridizing process on some of the portions of their ore which had resisted concentration. The Malm process was used but was abandoned when it was found that there was not enough zinc in the ore to allow economical treatment of the ore in question, as the Malm process depends upon step precipitation of the various metals in solution until finally a solution of zinc chloride is left which is evaporated and electrolyzed. If the zinc is not present in the ore, it must be added.

During the experimental work on the Malm process, some observations had been made on the effect of brine solutions on chlorinated ore, which finally led to the conclusion that most of the galena of the ore, even in an atmosphere of chlorine, was being converted largely to sulphate of lead, and that this sulphate of lead was soluble in a saturated brine. This was checked up by direct experiment and proved to be a most useful fact in the further development of a process. The brine had been used due to its known solvent power for silver chloride and lead chloride. Earlier in their work the Malm company had found that the solubility of lead

chloride in saturated solutions of salt is considerably increased over that in water, due doubtless to the formation of a double salt, and since they did their work, the solubility of the $\text{PbCl}_2\text{-NaCl}$ system has been published in the *Compt. Rend.*, confirming their results. At the plant of the Bunker Hill and Sullivan company it was found that the lead had been extracted from the Bunker Hill and Sullivan ore due to the fact that the sulphate of lead was also soluble in the brine.

With these facts in mind, Mr. Handy of the Bunker Hill and Sullivan company decided to try roasting the ore with a small amount of salt, in order to chloridize the silver of the ore and allow the lead to either chloridize or to form sulphate as it pleased. This left the ore in a condition such that all of the lead and much of the silver was soluble in a saturated solution of common salt.

In co-operation with the Bunker Hill and Sullivan company, the Salt Lake station of the Bureau of Mines took up the investigation of this process at this point. Under the direction of C. L. Larson, who at that time was connected with the Metallurgical Research Department of the University of Utah, an investigation was made of the possibility of applying the Holt-Dern roaster to the chloridizing of the Bunker Hill and Sullivan ore. Exclusive of the salt, this roaster had shown a cost of 16 cents per ton for roasting, at the mill of the Mines Operating Company at Park City, Utah. The Bunker Hill and Sullivan ore only contained 4 per cent sulphur, but Larson was able to roast it without the addition of fuel, and at the same time he got good extractions of the lead upon leaching with brine. As to the details of the process, which has been developed by the Bunker Hill and Sullivan company, these will be given to the public at such a time as may suit the convenience of the company. In the meanwhile, an experimental plant is being operated to collect data on the best temperature of the solution to use and to work out other data necessary for installing the process on a commercial scale.

The Bureau of Mines is now attempting to apply this process, without roasting, to the carbonate ores of lead. In doing so, it has been found that most of such carbonate ores yield their values to a saturated brine solution containing enough sulphuric acid to convert the lead to soluble sulphate or chloride. Natural sulphates of lead, while somewhat rare, and always accompanied by carbonate, will dissolve in the neutral brine. On running in cycles it has been found that sulphate of sodium or any other sulphate does not accumulate in the solution but seems to stay behind in the ore, due to the fact that sodium sulphate is not very soluble in a saturated brine. Consequently, as many as thirty complete cycles have been run without deterioration of the solution.

Following up Christensen's work, it has been found that the electrolysis of brine gives a spongy lead. Unlike any other spongy metal deposited from solution, it is perfectly feasible to melt this sponge lead into bars without serious oxidation and even when it does oxidize to some extent a very small amount of reducing agent will reduce the lead with ease. Such a thing is not possible with copper or zinc sponge. Furthermore, with the use of an iron anode, iron will go into solution, thus lowering the operating voltage, so that with a current density of 69 amp. per square foot at the cathode, only half a volt is necessary, and the solution can be almost stripped of lead before the current density must be reduced. Under these conditions the almost unbelievable amount of 70 lb. of lead per kilowatt-hour can be removed from the solution as a sponge which settles into the bottom of the cell where it can be compacted and

removed to be melted down. Furthermore, this spongy lead will not short-circuit the electrodes and hence the cells can be operated without much care. The iron going into the solution does not seem to affect the purity of the lead melted down and does not build up in the solution to much more than 1 per cent, some of it seemingly remaining in the ore.

The future of such a process is hard to predict but with such a great amount of mill solvent as the Great Salt Lake contains, it would look as though the low-grade carbonates of lead in Utah might be profitably treated by leaching instead of by furnacing. At least they could be concentrated into a 70-80 per cent product before going to the furnaces, and with a high extraction of the metal. Lead carbonates often have a bad tendency to slime and be lost in the tailing of a concentrating mill, but slimes need not interfere with a process of this kind. With several mills testing out the process, the developments in 1916 will doubtless be of considerable interest, both technically and commercially.

The Cost of Flotation

In a paper presented to the A. I. M. E. by J. M. Callow, the author gives the following data on the cost of flotation as practised by his pneumatic process, which was described in this journal Sept. 1, 1915:

Oil.—The oil mixtures generally in use cost from 1.25 cents per pound up to 3 cents per pound, depending on the percentage of creosol and other higher-priced oils used; on most ores $1\frac{1}{2}$ cents per pound is a safe average figure, and a consumption of 1 to $1\frac{1}{2}$ lb., or from 1.25 cents to 4.5 cents per ton of feed, averaging $2\frac{1}{2}$ cents, would be a safe estimate.

Labor.—This will vary, of course, with the size of the plant. At one plant, consisting of 60 cells, two men per shift operate the entire plant, equivalent to a cost of $1\frac{1}{4}$ cents per ton. One man per shift on a 250-ton plant means a cost of 5.4 cents per ton maintenance. Assuming a life of three months per blanket, a capacity of 50 tons per cell, and an allowance for repairs to blowers, motors, pumps, etc., we have $\frac{1}{2}$ cent per ton as a liberal allowance.

Power.—With power at 1 cent per kilowatt-hour, and a consumption of $2\frac{1}{2}$ kw-hr. per ton, the cost would figure 2.5 cents per ton of feed.

Summarized, the estimated cost on a 2000-ton flotation plant, or larger, would be approximately as follows:

	Per Ton, Cents
Labor	1.25
Oil	2.50
Maintenance	0.50
Power	2.50
Total	6.75

On a plant of 250 tons the extra labor costs per ton would bring it up to approximately 10 cents per ton of flotation feed.

Actual figures from a large plant treating over 2000 tons by flotation gave 6.1 cents per ton; the flotation feed in this case represents 60 per cent of the crude ore tonnage, making the cost 3.5 cents per ton of crude ore treated.

Byproduct Coke Oven Plant.—The Indiana Coke & Gas Company of Terre Haute, Ind., has placed a contract with the Gas Machinery Company of Cleveland, Ohio, for a byproduct coke-oven plant, consisting of thirty cross regenerative byproduct coke ovens and apparatus for the recovery of tar and ammonia. Indiana coal will be used and the coke will be sold, for the time being, for domestic uses. The surplus gas will be delivered to the Terre Haute Gas Company for local consumption.

A Form for the Classification of Flotation Data

BY W. A. WHITAKER AND GEORGE BELCHIC

The increasing importance of flotation as a method for ore concentration and mineral conservation is illustrated by the fact that many private corporations, as well as university laboratories, are now engaged in investigating this process. Most of these investigators have as their object the defining of the conditions necessary for successful flotation when applied to particular material, while others are engaged in purely theoretical work looking toward an explanation of the various phenomena upon which flotation is based. Whatever the object sought, the investigation, if prosecuted to any extent, will result in the accumulation of a large amount of minute data, which unless arranged in such a way as to allow of ready comparison and correlation, may soon become a mass of unwieldy material, difficult of clear interpretation.

In order to compile in a condensed arrangement the results obtained in this laboratory and thus allow of quick and easy comparison and correlation, the form

illustrated below was evolved and printed in quantity. With this arrangement, the investigator has before him on one sheet (1) the screen analysis, (2) the assays, (3) the charge used, (4) the derived data, and (5) the plotted efficiency of the frothing agent.

The same form may be used also when the effects of other flotation factors are being investigated, such as variations of temperature, duration and speed of agitation, quantity of acid, etc. This condensed scheme has worked so satisfactorily in this laboratory, it was thought that its publication might be helpful to those who are beginning investigations on flotation and possibly to those already launched upon the subject.

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University of Kansas,
Lawrence, Kan.

Reverberatory Smelting at Consolidated Arizona Smelting Company, Humboldt, Arizona

(Editorial Correspondence)

In a previous article in this journal¹ we described in detail the concentration of copper ores by flotation at Humboldt, Ariz., and gave many valuable data on the method and cost of operation. In conjunction with the concentrator, the company operates a smelting plant for the treatment of its own ores and concentrates and certain ores bought on a custom basis. The custom business is being built up as rapidly as the development of the district warrants. Smelting is done in oil-fired reverberatory furnaces, and copper is produced from matte in basic-lined converters. Production has averaged about 500,000 lb. of blister copper per month, two-thirds to three-fourths of which is from company ore and the balance from custom material. Costs of operation and production will be officially announced by the company in the near future.

The equipment of the plant consists of one seven-hearth Wedge roaster, 21 ft. 6 in. diameter, fitted with auxiliary oil burners; one 19-ft. by 60-ft. and one 19-ft. by 100-ft. reverberatory furnaces, the latter being under construction and practically completed at the time of writing, and two 9-ft. 6-in. diameter barrel-type basic-lined converters.

Table I gives in condensed form average analyses of some of the materials treated and products made. Gold

TABLE I.

	Au.	Ag.	Cu.	Insol.	Fe.	CaO.	S.
General mill conc.	0.09	3.04	9.52	16.5	30.0	—	—
Smelting ore	0.04	1.50	3.70	48.0	20.0	1.3	22.0
Roaster feed	—	—	6.00	20.0	30.0	1.4	20.0
Calcine	—	—	6.20	23.5	35.5	1.4	9.0
Reverberatory slag	—	—	0.35	38.0	38.0	0.8	—
Matte	—	—	35.00	—	—	—	—
Blister copper	1.00	28.00	99.10	—	—	—	—

and silver are indicated in ounces per ton and the other constituents in per cent.

In addition to the company's own products, a considerable tonnage of custom ore is treated, a large portion of this being a copper-bearing specular hematite containing 43 per cent iron and 10 per cent insoluble. Converter flux and fettling material is highly silicious copper ore from the upper levels of the company's mines, and contains 3.8 per cent copper and from 70 per cent to 80 per cent insoluble. In this ore the copper minerals are more or less oxidized and not well suited to concentration, particularly flotation, tending to "kill" the froth in the latter process.

It will be noted that all material entering the plant at any stage of the process is copper-bearing. Barren material is excluded, and by this practice every flux adds

Flotation Experiments

Number of Sample 6 Date May - 1915
Assay { Zinc = 5.17 % Number of Experiment 12
 { Lead = trace

SCREEN ANALYSIS

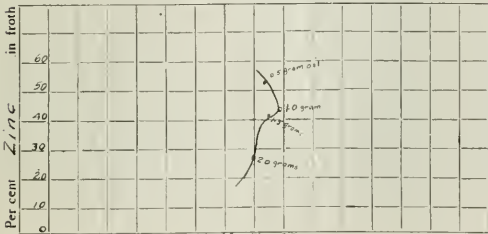
	SCREEN		WEIGHTS			ASSAYS	
	Mesh	Opening Inches	Sample Weight grams	Per Cent.	Per Cent. Accumulative Weight	% Zinc	
All Pass	35	.0164					
Retained	48	.016	2.0	0.417	9.417		
"	65	.0254	3.0	0.625	16.042	2.4	
"	100	.0058	9.0	1.875	26.917		
"	150	.0041	34.0	7.08	33.995	3.8	
"	200	.0029	85.0	17.70	51.695	4.58	
Pass thru	200	.0029	347.0	72.30		5.56	
Totals			480.0	100.0			

To show the effect of variation in quantity Pine Oil

CHARGE		Variable grams	DERIVED DATA			
Ore, grams	400		Froth	Assay of Con.	% Ext	
Water, "	1200	0.5	29.0	53.2	—	74.6
Acid, H ₂ SO ₄	2.0	1.0	38.0	43.1	—	79.2
Oil, "	Variable	1.5	37.0	42.4	—	75.8
Temp. in °C	65	2.0	51.0	28.6	—	70.0
Speed, RPM	2000					
Time, minutes	7					

EFFICIENCY CURVE

Efficiency of Pine Oil in terms of frothy assay and extraction.



Per cent extraction

Zinc

¹December 1, 1915, p. 897.

its quota of copper while serving the purpose of producing the desired slag. In this respect the practice under the present management is an economic improvement over that of an earlier period when blast-furnace smelting was practiced and barren fluxes were purchased.

Roasting Flotation Concentrates

Roaster feed is a mixture containing smelting ore, general mill concentrate and copper-bearing iron oxide. Due to the fact that about 75 per cent of the general mill concentrate is a flotation product, 60 per cent of which is finer than 200-mesh, the general concentrate contains from 40 per cent to 45 per cent of material of that mesh and finer. The smelting ore and iron oxide are crushed to only $\frac{1}{2}$ -in., but even so, the roaster feed still contains a large percentage of very fine material. This naturally gives rise to excessive dusting in the roaster, demanding special attention to dust recovery in order to avoid a serious loss.

Roaster capacity with this feed is 110 tons per day. The sulphur content of the feed is maintained at about 20 per cent, and as long as it is 17 per cent or more there is no need of applying extraneous heat to carry on the roasting process. Oil burners are provided at the hearth doors, however, for use in case of necessity.

Typical roaster feed is composed of the following constituents by weight, and has the general analysis given in Table I:

Smelting ore	600 lb.
Specular iron ore	3,400 lb.
Mill concentrate	6,000 lb.

To this mixture, in the form of calcine, is added the following cold material to make up the reverberatory charge, the total weight being the charge per hour and six minutes, fed at thirty to thirty-five minute intervals:

Converter slag	1,500 lb.
Specular iron ore	2,500 lb.
Mill concentrate	1,500 lb.

It will be apparent that, when fettling material is included, an unusually large part of the total furnace charge is cold material, amounting roughly to 50 per cent. The conditions are quite different to those prevailing in plants where the reverberatory charge is practically all hot calcine and fluid converter slag. This accounts for the comparatively high fuel ratio, which is one barrel of crude oil per ton of total charge. The oil is preheated to a temperature of 160 deg. Fahr. and is fed to the burners under 70-lb. pressure. The furnace is equipped with two 350-hp. Stirling waste-heat boilers, but no very positive data are available from which to calculate a credit to oil consumption represented in heat recovery at the boilers. Under the conditions imposed this 19-ft. by 60-ft. reverberatory furnace has a daily capacity of 165 to 175 tons. The average grade of furnace charge and products is shown in Table I.

The new reverberatory, 19 ft. by 100 ft., is constructed with a continuous hopper across the bridge and along the side walls. Fettling will be done with a blended neutral mixture through pipes from the side hoppers instead of by hand in the old manner. Due to the character of the material to be smelted, the charge for this new furnace will be temporarily on a basis of 30 per cent calcine and 70 per cent cold charge, the latter being in even greater ratio than in the smaller furnace at the present time, although it is probable that this will be modified by providing additional roaster capacity at a later date.

Intermittent Use of Basic-Lined Converters

Converter capacity is far in excess of requirements when only the small reverberatory is in operation. This results in the intermittent use of a shell, and the prac-

tice here has thrown valuable light on the use of basic-lined converters under such conditions. The question has previously been raised as to whether converters of standard size lined with basic brick could be successfully used in comparatively small plants where intermittent operation would be necessary on account of the small output of matter. It had been feared that the converter would be subjected to such severe treatment due to the expansion and contraction of the brick lining that its use under these conditions would be unprofitable. This question was raised in the copper symposium at the International Engineering Congress in San Francisco, and at that time Mr. Laist stated that the basic-lined converter had been found to stand hard usage in intermittent service, with little cracking of the lining.

Experience at the Humboldt smelter confirms this fact, for under the method of operation no serious difficulty has been encountered. When a new lining is put in service, a number of charges are blown at short intervals to saturate and bond the brick with metal. After the lining is thus seasoned the converted will be idle for seven to eight hours between blows. On occasions a shell has been idle as long as thirty hours after a blow. According to conditions and the probable length of time the converter is likely to be down, the lining is kept warm by adding a charge of fuel, but otherwise no provision is made for the care or protection of the lining. No data are available as to production per converter lining, as the converters have not been in operation for a sufficient length of time to get any direct figures.

While magnesite brick has proved satisfactory under these conditions, Mr. E. C. King, smelter superintendent, plans to try a monolithic lining of magnesite bonded with silicate of soda or magnesium sulphate. This will be done with the idea of securing a less expensive lining, and at the same time one which may show an improvement over the use of brick.

With the new 100-ft. reverberatory in use, the smelting capacity of the plant should be increased to 450 tons per day, with a monthly production of about 1,000,000 lb. blister copper. At present the company is not equipped for blast-furnace smelting, but the erection of a blast furnace is in prospect if mining conditions in the district develop as anticipated so that a supply of suitable ore can be assured. With the ores just now available blast-furnace smelting is out of the question as a matter of economy and good metallurgy.

Our thanks are due Mr. Colvocoresses, general manager, and Mr. King, smelter superintendent, for their courtesy in favoring us with the foregoing information.

Mesothorium, a by-product from the manufacture of thorium nitrate from monazite, has properties similar to those of radium. It is considered possible that this country's resources of monazite can be used profitably in the manufacture of this valuable material. The domestic supply of monazite is found mainly in North and South Carolina, Idaho, and in the black sands of the Pacific slope.

New Regulations Governing Export Procedure.—The announcement that new United States regulations relative to export procedure will become effective Jan. 1, 1916, has created such intense interest among manufacturers and shippers that the Bureau of Foreign and Domestic Commerce, Department of Commerce, has found it necessary to reprint the new order with explanatory text. That pamphlet is just off the press and is being supplied free of charge to those interested, upon application to the above-mentioned office. All shipments for export to foreign countries or to Alaska, Hawaii and Porto Rico will be affected by the new regulations.

The Central Mill of the North Star Mines Co.

BY LEROY A. PALMER

In the Sept. 15 issue of METALLURGICAL AND CHEMICAL ENGINEERING I discussed two mills in the California gold belt, one practicing amalgamation and concentration and the other straight cyanidation. This article will deal with a mill that uses all three processes. Mills that amalgamate and then either concentrate or cyanide the tailings are common, but the process in vogue with the North Star Mines Company is unique in that following amalgamation the tailing is concentrated and the concentrate subsequently cyanided with the concentration tailing.

The North Star Mines Company operates three mills, the Champion at Nevada City and the Central and North Star at Grass Valley, Nevada County, Cal. The ore carries both gold and silver in a quartz gangue, the precious metals occurring both free and associated with pyrite, galena and sphalerite. The same process obtains at all of the mills of this company and the following on the Central mill may be taken as generally descriptive.

The ore is hoisted from the Central shaft in automatic dump skips to the bins, from which it is hauled in electric trains with side dump cars to both the North Star and Central mills, the latter being only 200 ft. distant from the head-frame. The mill, Fig. 1, which has a nominal rating of 160 tons daily, is of timber frame with corrugated iron sheathing and concrete floors, and so set on a hillside that all conveyance of ore is by gravity.

Wet Crushing

The ore is dumped into two bins, each of 200 tons capacity, fitted with 1½-in. grizzlies. The oversize of each grizzly goes to a 9-in. by 15-in. Blake crusher set to 1½ in. These crushers are run wet and discharge to that portion of the bin beneath the grizzly. A 15-hp. motor drives both crushers at a speed of 180 r.p.m. The ore is fed to them from rack and pinion gates through a steel chute fitted with vertical grizzly bars which can be dropped across it to check the flow of ore and allow waste rock to be sorted out. In this way about 5.5 per cent of the ore sent to the mill bins is rejected without going through the crushers.

Masonry Mortar Block and Steel Battery Posts

The mill has forty stamps driven as four batteries by a 100-hp. motor, but working in five-stamp mortars, Fig. 2. The stamps weigh 1050 lb. and make 107 7-in. drops per minute in order 1-5-2-4-3, with 6-in. discharge. The feed is from Challenge feeders driven

from the middle stem of each five stamps. Stamping is done through a steel screen with punched round holes 1/25 in. in diameter. At intervals of 1 in., laterally and vertically, a strip 1/16 in. wide is left unpunched for reinforcement. Such a screen gives an open area of 0.362 sq. in. per square inch of surface and has an average life of twenty days with an issue of 20 tons per day.

There are many points of interest about the batteries at the Central. First is the masonry foundation. When the mill was built in 1904 most designers clung to the old wooden battery-block. Masonry or concrete was looked upon with suspicion as it was considered that the mortar foundations must possess a certain amount of resiliency. The foundations at the Central are of granite bound with cement mortar, with concrete tops in which a rubber bedplate 1/32 in. thick is set so as to make a water-tight joint between the mortar and its foundation. The tunnel which frequently forms part of a battery foundation to permit tightening the nuts of the anchor bolts has been omitted in this construction, and the bolts are solidly embedded in the masonry. This practice has been very satisfactory as there has been no breakage of bolts or mortars and loose nuts are of rare occurrence.

Another feature is the steel battery posts at which so many millmen are inclined to look askance. Each post is made of two pairs of 8-in. channel irons bolted to the foundation and with a 4-in. spreader between the channels of each pair. This style of frame has been in continuous use since the mill commenced operation, with the failure of only four posts. When breakage has occurred it has been of a single channel iron at a time. In such a case the camshaft bearing is jacked up and the broken channel removed and replaced without stopping the battery. The advantage of this rigid construction has been well exemplified at the North Star mill of this company. With wooden battery frames the breakage of camshafts ran as high as eleven in a single year. At this latter plant cast-iron battery frames were substituted about a year ago and, as a result, the breakage reduced to four in that time, a favorable showing considering the weight of the stamps and the speed at which they are run.

The screen frame used is out of the ordinary. It is a double frame, one piece fitting inside the other and bearing against a face 1 in. wide around the inside of the outer frame. Instead of being tacked on, the screen is laid in the outer frame against a rubber gasket; the inner frame, which is of cast iron to obviate swelling, is laid against it and secured by three iron buttons. In fact, the screen is held in its frame in practically the same manner that the glass is held in a picture frame. It can readily be seen that this method



FIG. 1—CENTRAL STAMP MILL IN BACKGROUND, CYANIDE PLANT IN FOREGROUND

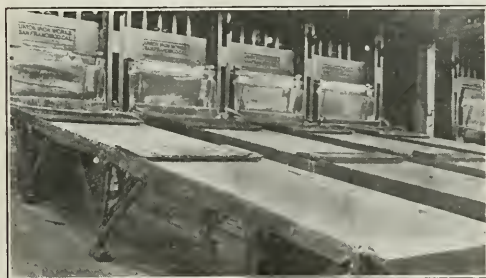


FIG. 2—CENTRAL MILL—BATTERIES AND PLATES SHOWING STEEL BATTERY POSTS

effects a considerable saving of time in setting up screens as compared with tacking them to their frames.

In place of the ordinary chuck-block for inside amalgamation, rifle-blocks with a height of 6 in. are used. Lengthwise of these blocks are stapled six rods of $\frac{1}{4}$ -in. square iron which act as rifles to catch and retain the amalgam. This arrangement permits of running the battery with lower discharge, and consequently faster crushing and less sliming, than with the regular chuck-block. The amalgam is easily cleaned from the rifle-blocks, most of it dropping off by simply tapping the block when it is removed from the mortar and the remainder scaling off readily with a sharp instrument such as the point of a taper file.

Stamp stems are of uniform thickness throughout instead of being tapered at the ends to fit in the boss-heads. In place of the tapering end a two-part tapered bushing of $\frac{1}{2}$ -in. steel is used. This is set in the hole in the boss-head with the straight stamp stem inside it. In case a stem breaks, instead of taking it out of the guides and turning it around, the bushing and broken part are driven out of the boss-head by means of a drift, the stem is reset in the bushing without reversing, the tappet is set up and the stamp is ready for operation.

New Design of Cam

The latest innovation is the new cam designed by Arthur B. Foote, general superintendent, which is going into use in these mills and is illustrated in Fig. 3. It was found that with the speed at which these stamps

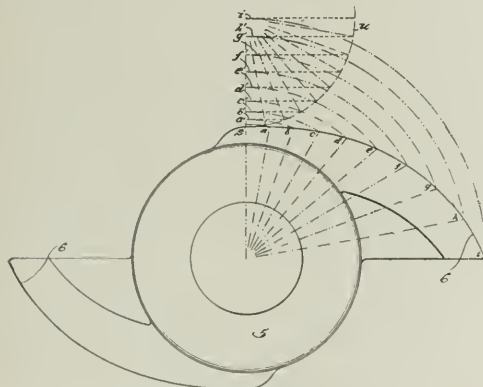


FIG. 3—CAM FOR STAMPS

were dropped, cams and shafts were frequently broken. Aside from torsion, to which any shaft is subjected and which is greater than usual in a camshaft due to the weight lifted, a camshaft is necessarily subjected to two strains. These strains are due to the impact of the cam engaging the tappet and the jar of the stamp transmitted to the shaft through the mortar, block and battery frame. If the mortar and block are well built and the battery frame rigid, the latter strain is negligible and the most serious effect on the shaft is due to the jar of the cams picking up the tappet, which this new cam is designed to reduce to a minimum.

As is well known, the cam which has been in universal use for years past is laid out on the slightly modified involute of a circle. This new cam can best be understood by referring to the accompanying illustration. The distance from the center of the shaft to i' is equal to the major radius of the cam. From s to i' is the throw. With i' as a center and $i's$ as a radius, a quadrant is struck and divided into nine equal parts,

each subtending an angle of 10 deg. Horizontal lines drawn from these points on the arc divide the vertical radius into parts, sa' , sb' , sc' , etc., representing the sines of 10 deg., 20 deg., 30 deg., etc., respectively. A similar quadrant with a radius equal to the major radius of the cam is struck from the center of the shaft and likewise divided into 10-deg. arcs.

The curve is then laid off by striking an arc from the center of the shaft, the radius of which is equal to the distance from this center to a' until it intersects the radius a of the major arc, thus fixing the first point of the curve. Subsequent points are fixed by striking an arc from the center to b' until it intersects radius b ; from the center to c' to intersect radius c , and so on. The effect is a curve which may be likened to the spiral in a railway track, giving a radius which increases uniformly and thus imparts to the cam a uniform acceleration of speed such that when it finally disengages the tappet the velocity of the stamp is sufficient to carry it still farther upward and give it a drop greater than the actual throw of the cam.

It is claimed for this cam that it picks up the stamp with less jar than the involute design, a point that can be demonstrated by feeling the tappets of the two in operation. It requires special design for different drops as the blow on the tappet increases as the drop is shortened until at one-half the drop for which the cam is designed the shock of cam and tappet engaging would be the same as with an involute cam. Wear on the tappets is greater than with the involute design but breakage of cams and shafts, much the greater evil, is less. The designer makes no claims for it as a cure-all for battery troubles and recommends it only where there has been trouble from breakage due to high speed.

High Recovery by Amalgamation

From the batteries the pulp flows over eight amalgamation plates each 3 ft. by 20 ft., supported on frames made of angle irons, with a grade of $2\frac{1}{4}$ in. per foot. The recovery by amalgamation is about 79 per cent, an unusual amount on California ores. The rifle-blocks are cleaned every fifteen days and yield about 65 per cent of the free gold recovered. The battery plates are cleaned daily and yield most of the remainder. Traps are provided below the plates and small plates below the tube-mill, but the recovery from these sources represents only a small percentage of the total. About 100 to 130 oz. of mercury is charged daily.

On clean-up days one of the mortars is fitted with a 30-mesh screen and all sands from the clean-up and all "specimen" ore are run through this battery. The tailing from this treatment and the sand left around the dies when the battery is opened are collected in a tank and returned to the mill bin for retreatment. Sand from this clean-up is treated in a bowl, the overflow of which is settled in a concrete sump.

Concentration

After passing the traps the tailings from each of the eight plates go to a Dodd buddle, Fig. 4. This is an outward-sloping, circular-deck table, 8 ft. in diameter, with linoleum cover and annular rifles. It is driven by a head motion in which the action is transmitted through a crank with a speed of 190 r.p.m. and a throw of 1 in., so connected to the deck that the latter moves forward and back in the arc of a circle. The rifles are spaced $1\frac{1}{2}$ in. apart, and stratify the pulp, which is fed at the center, on the same principle as the quadrilateral deck tables. Beneath the deck of each table is a small spiral pump which receives the middling and discharges it through a hollow central shaft. These tables make concentrates, middlings and tail-

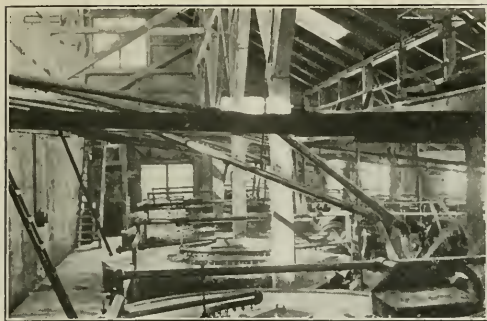


FIG. 4—CENTRAL MILL—DODD BUDDLES

ings. The concentrates go to a tube-mill for regrinding, the tailings are laundered to the cyanide plant and the middlings are sent by their individual pumps to the feed box of a ninth buddle, which makes the same products but retreats its own middling.

Tube-Milling of Concentrates

The concentrates from the buddles go to a 2½-in. centrifugal pump, which elevates them to a 24-in. de-watering cone. The overflow of this cone goes to the tail race and the underflow to a 5-ft. x 10-ft. tube mill which makes 14 r.p.m. The tube uses Danish pebbles and crushes so that 97 per cent of its product will pass a 200-mesh screen. Because of the nature of the feed both pebble and power consumption are low, a 20-hp. motor driving the tube mill and the nine buddles.

The tube-mill product is run over a 3-ft. x 6-ft. amalgamating plate, and thence to a 24-in. cone. The overflow of the cone goes to the cyanide plant and the underflow is returned to the tube mill by way of the centrifugal pump.

Thus the sulphides, after being separated from the gangue as concentrates, are crushed and again mixed with it, prior to cyanidation. The sole object in the concentration is to reduce the amount of fine grinding necessary in preparing the plate tailings for further treatment, and in actual practice the buddles may be said to act as classifiers for the tube mill, the classification being gravimetric instead of volumetric.

It has been found that such precious metal as can be recovered from the concentration tailing by cyaniding is amenable to this treatment without further crushing than that given in the batteries. On the other hand, the gold occurring with the sulphides is intimately associated with them and fine grinding is necessary to free it sufficiently for the solutions to act on it.



FIG. 5—OLIVER FILTERS, PACHUCA AND DECANTATION TANKS

As concentration is effected at a ratio of 40 to 1 this separation eliminates 97½ per cent of the tonnage from tube milling. The saving in power and pebble consumption is even greater than this, as the tailings are all quartz and the concentrates, the tube-mill feed, being sulphides, are much softer and more friable.

Cyanidation of Sand and Slime

The cyanide plant is situated about 500 ft. from the stamp mill at such lower elevation that the feed may be delivered at the top floor by gravity. The mingled tailings and concentrates, which classify as about 60 per cent slime and 40 per cent sand, are delivered to a 5-ft. sloughing-off cone. The underflow of this cone goes to two more 5-ft. cones, the overflow of which is divided between two 5-ft. x 6-ft. V settlers. The underflow of the second cone and the settlers goes by means of a Butters distributor to a leaching vat, of which there are six, each with a capacity of 125 tons.

Slime Treatment

The overflow of the various settlers mingles and is distributed by launders to six cone-bottom settling tanks, each 10 ft. x 12 ft. and to one Dorr thickener. The settler overflow is used as wash water on the leaching vats. A preliminary charge of lime is added at the settlers and the Dorr thickener, and the pulp drawn off at sp. gr. 1.30 to a stock tank in which sufficient lime is added to bring the strength up to 0.01 per cent; and cyanide of sodium to make the strength of the solution 0.03 per cent. This is equivalent to 0.0375 per cent, or 0.75 lb. KCN per ton of solution.

The pulp in the stock tank is agitated by compressed air and transferred by a Pohlé lift to the first of three Pachuca tanks, each 8 ft. by 15 ft., through which it is passed in series. From the last Pachuca the pulp is divided between two decantation tanks, the underflow from which goes to two Oliver filters and the overflow to the filter-solution sump. The Oliver filters make a revolution in 4 min. 20 sec., and receive a barren weak solution as a wash. The pulp is then wasted.

Details of Sand Treatment

After a leaching vat has filled and drained, the first treatment is by pumping on pregnant solution from the Oliver filter and the decantation tanks. These solutions are collected in a 450-gal. sump and raised by a 4-in. pump to the vat where they are brought up to a standard of 0.10 per cent NaCN. Thirty tons are thus pumped onto the sand and allowed to drain through. Thirty tons of strong solution, 0.10 per cent NaCN, are then run on and allowed to stand twenty-four hours. At the expiration of this time the valves are opened, and three hours after sand shows, filter solution is again run on until the sand is covered, when the vats are allowed to drain completely. The filter solution being drained, seven 15-ton charges of weak solution, under 0.06 per cent NaCN, are pumped from the sump below the Merrill presses, the vats being aerated by draining between charges until the sand appears. With the final draining of the weak solution the sand is washed for six hours before discharging with the lime water which overflows from the slime settlers.

When a vat is ready for discharging the valves, which are of Butters type, are raised, and a hose with a long nozzle thrust down beside each valve to start the sand out. When a channel is once made a Butters distributor is swung over the vat, a good head of water turned on and no further attention required except to sluice out a little sand which clings to the sides and bottom and which the distributor fails to dislodge. In this manner

a 125-ton vat can be emptied in about two hours' time with practically no personal attention.

Precipitation by Zinc Dust

The effluents of the leaching vats are titrated and sent to the pregnant strong or pregnant weak sumps, according as they are over or under 0.06 per cent NaCN. From these sumps they are pumped, after the addition of zinc dust, to one of two 10-frame, 30-in. Merrill filter presses. The precipitate is fluxed and melted without previous roasting or acid treatment.

Consumption of Chemicals and Power

The stamp mill uses about 0.75 oz. mercury per ton of ore treated. An average for a year in the cyanide plant showed consumption of chemicals per ton as follows: Sodium cyanide, 0.502 lb.; lime, 3.50 lb.; zinc dust, 0.192 lb.

Two motors are used in the cyanide plant, a 10-hp. belted to a 16 by 10-in. Rix single-stage compressor, which furnishes air at 15 lb. for the Oliver filter, Pohlé lift and Pachuca tanks, and a 20-hp. motor belted to a counter shaft, which drives all of the other machinery, including a No. 4 Roots cycloidal blower, which produces vacuum at 20 in. on the Oliver filter.

The following is a summary of all motors:

Machines	Motors	Horse-power
2 Blake crushers.....	1	15
40 Stamps.....	1	100
8 Buddies.....	1	20
1 Tube mill.....		
1 Centrifugal pump.....	1	10
1 Air compressor.....	1	10
3 Pumps.....	1	20
1 Root's blower.....		
Total.....	5	165

This indicates a consumption of 1.03 hp. per ton per day. A segregation of power costs for an average month shows cost per ton of ore as follows:

Crushing and stamping.....	\$0.126
Concentrating and tube-milling.....	.016
Cyaniding.....	.036
Total.....	\$0.178

Power is purchased from the Pacific Gas & Electric Company, which has extensive hydro-electric developments in this vicinity. The main transmission is at 40,000 volts; it is stepped down to 4000 for transmission to the mine, and there stepped down to 440 for use in the mills.

Extraction and Costs

An average value of the ore milled from the North Star mines would be very close to \$10 per ton. Extraction is at the rate of 97 per cent, leaving a tailing loss of 30 cents per ton. Costs of operation for the year 1914 were as follows:

Crushing, stamping and amalgamating.....	\$0.423
Concentrating and tube milling.....	.117
Cyaniding.....	.396
Total.....	\$0.936

Most of the mills in California, especially the smaller plants, treat their ores by amalgamation and concentration, and ship the concentrates to the smelters. This practice was followed by the North Star for some time so that some comparison of the two methods can be made. Seventy-nine per cent, or \$7.90 per ton, is recovered by amalgamation. Thirty cents is lost in the tailings, so that \$1.80 is recovered by cyanidation. This costs \$0.396 per ton plus the cost of tube milling, which will approximate 6 cents a ton. Treasure freight and mint charges amount to \$0.0075 per ton of ore treated, so that this charge on the cyanide bullion would amount to \$0.0014 per ton of ore, giving a total of \$0.46 for all charges made necessary by cessation of shipment of con-

centrates. This leaves a net profit of \$1.34 per ton from the plate tailings.

At a new mill on the Mother Lode in which a somewhat similar ore is concentrated the recovery on the vanners is 72 per cent. Applying these figures to the North Star the recovery from concentration would be \$1.51 per ton. The smelter paid for 92 per cent of the gold at the rate of \$19.50 per oz., so that the amount paid by the smelter for the concentrates from a ton of ore would be \$1.31. Freight and treatment charges amount to \$10 per ton of concentrates, or \$0.25 per ton of ore with a concentration ratio of 40 to 1. Thus the net return per ton of ore concentrated would be \$1.06, a difference in favor of cyaniding of \$0.28 per ton.

I am indebted to Mr. Arthur B. Foote, general superintendent, and Mr. Frank Provis, foreman of the Central Mill, as well as other employees of the North Star Mining Company.

San Francisco, Cal.

The Mechanical Principles of the Blast Furnace

BY J. E. JOHNSON, JR.

The opinion that the mechanical principles of the blast furnace are insignificant in number and importance has been quite generally held, and the subject has been correspondingly neglected, but in my judgment this view is founded on superficial observations, since the proper mechanical action of the furnace is the key to its successful commercial operation. There are two main requirements of mechanical action of equal importance since the fulfillment of both is vital to the process. These are: first, that the stock must settle uniformly over the whole area of the furnace and at as regular a rate as possible; second, that the gas formed by the combustion in the hearth must rise with similar uniformity of distribution and velocity so that each portion of the charge shall receive its share of the action of the gas.

In the early days of blast furnace operation there was little or no conflict between these two requirements, but with the increase in the rate of driving previously described they have become to a certain extent conflicting because of the resistance to the descent of the stock column offered by the ascending current of gas. The gas is driven through the furnace by mechanical power, and the amount of pressure which we can put upon it is in recent years virtually unlimited, so that the gas (blast) pressure has risen as fast as there was any need for it to do so; in some cases, one might almost say, faster. But the force causing the descent of the charge column is simply that of gravity, which we cannot increase except by increasing the height of the furnace, and the net result of that remedy, as I shall presently show, is to make conditions much worse instead of better.

Our first care must obviously be so to distribute the charge in the top of the furnace that the resistance of all portions of the charge column shall be the same, as already pointed out in the chapter on filling the furnace. We know but little about the theory of stock distribution further than the necessity of placing a considerable part of the fine material against the walls on account of the greater proportion of voids at the surface of the wall. Under the head of operation we shall discuss this a little more fully, but there is not enough known on the subject to be of use in this discussion, further than the above.

The Blast Pressure

Within quite recent years, and perhaps even now, there is a very considerable misapprehension on the

subject of the cause and function of the blast pressure. This is made up of three parts, the pressure required to drive the air through the tuyeres, that required to force it up through the charge column, and that to force it from the top of the furnace out through the down comer and flues. These three items make up the total blast pressure just back of the tuyeres, while to obtain the engine house pressure the pressure due the resistance of the hot blast main, the stoves, and the cold blast main must be added, the sum of which should not exceed $\frac{1}{2}$ lb. in good practice.

Many people have thought that the greater portion of the whole pressure was expended in driving the blast through the tuyeres, and that the resistance of the stock column was almost a negligible quantity, but nothing could be further from the facts. The pressure required to drive the blast through the tuyeres is in ordinary practice only about 10 per cent of the total pressure, and almost all the rest is expended in overcoming the resistance of the stock column. Finally from 1 to 3 per cent of the total is required to drive the gas through the down comer flues and burners.

In a paper published by me before the American Institute of Mining Engineers in 1905, entitled "Notes on the Physical Action of the Blast Furnace," there was given a discussion of this subject which, in the light of ten years' further experience, does not seem to require much modification, and is quoted here.

The Top Pressure

This is so simple that misconception would have seemed impossible had the attempt not been made to deduce results as to the quantity of flue-dust carried over at different furnaces from their top-pressures. The truth is that the top-pressure depends on the volume and density of the top-gases, and on the frictional resistance of the flues or mains through which they are forced, and on nothing else. The frictional resistance depends on the clear area, the length and the roughness of the mains.

Considering that the condition of the latter is generally a matter of entire uncertainty, as they vary in normal operation from perfectly clean to almost completely blocked with flue-dust and coke, calculations of the frictional resistance during operation are entirely worthless, as are also deductions as to the furnace work from the gas-pressure. If the top-pressure rises, the blowing engine automatically blows a little more pressure (never in good practice over $\frac{1}{2}$ lb.), so as to maintain the same difference between the pressure at the tuyeres and that at the top. As these variations are much smaller and much slower than those due to other causes, they are naturally never being noticed at the engine.

The Pressure Required for the Tuyeres Penetration

The pressure drop through the tuyeres has also come in for its share of misunderstanding. Within a few years the assistant to the superintendent (now superintendent) of the largest blast-furnace plant in the world contended with me strongly that the blast-pressure was nearly all expended in forcing the blast through the tuyeres, and that the pressure at the top of the bosh would not be over 2 or 3 lb. in a furnace driven with about 15 lb. He was at that time making experiments bearing on this subject, and soon found his error. This is, in fact, a matter on which we can make calculation with certainty, Fliegner, Zeuner and Weisbach having made experiments on the flow of air through orifices, and established formulæ therefor which are authoritative.

The formula for this case is

$$W = 63.6A \sqrt{\frac{P_2(P_1 - P_2)}{T_1}} \quad (1)$$

W being the weight in pounds of air passing each tuyere per minute; A , the area of the tuyere; P_1 , the absolute pressure outside the tuyere; P_2 , the absolute pressure in the furnace; and T_1 , the absolute blast temperature (= deg. Fahr. + 460).

One thousand cubic feet of air at normal pressure and 70 deg. Fahr. weigh exactly 75 lb. Since this is about an average normal condition, the conversion of volume to weight can be conveniently made on this basis (and is so made throughout this paper). Moreover, since the tuyeres are usually circular in section, we can convert the above formula to a more convenient form for immediate use, as follows:

$$P_1 - P_2 = 2.4 \left(\frac{T_1 V^2}{P_1 d^4} \right)$$

where V^2 is the volume of blast (free air) passing each tuyere per minute, measured in thousands of cubic feet, and d is the diameter of the tuyere in inches. This formula is not quite exact, being too high for low tuyere velocities and too low for high one; but it is accurate enough for the present purpose, under ordinary conditions.

For a furnace blown with 40,000 cu. ft. of blast per minute at 15.20 lb. pressure and 1000 deg. Fahr. temperature, through twelve 6-in. tuyeres, we have $P_1 - P_2$ = difference of pressure passing through the tuyeres =

$$2.4 \times \frac{1000 + 460}{15.2 \times 14.7} \times \frac{(3.3)^2}{6^4} = 1.0 \text{ lb.}$$

This is the difference in pressure required to give the necessary velocity through the tuyeres, and is, of course, fixed by the temperature, pressure, and volume of the blast, and the size of the tuyeres.

It will be seen that this pressure varies as the fourth power of the diameter of the tuyeres, so that it requires over twice the pressure to force the blast through 5-in. tuyeres under given conditions as to force it through 6-in. ones.

Other things being equal, the loss of pressure in passing the tuyeres varies as the square of the velocity, and the energy of the blast-jet also varies as the square of its velocity, hence the energy varies directly as the difference in pressure. This energy represents the ability of the blast-jet to overcome resistance in its line of action—in other words, its penetration; hence the penetration is proportional to the difference in pressure between the bustle-pipe or tuyere-stocks and the interior of the furnace. This explains the failure of many schemes of alternate small and large tuyeres, and tuyeres with flattened nozzles adapted to deliver a fan-shaped jet of air, which will cover the whole tuyere-plane equally (Gaines tuyeres). The difference of pressure, under given circumstances, within and without the tuyeres, is determined by the area of all the tuyeres, and hence the penetration in front of each of them is the same. Consequently, when alternate large and small nozzles are used, instead of the small ones throwing the air to the center and the large ones filling in the dead spaces between them, they all penetrate in figures of the same shape in the tuyere-plane; but the larger tuyeres make a larger and therefore longer one than the smaller—an effect the opposite of that intended.

Similarly the Gaines tuyeres distribute the blast so that the proper amounts are started in each direction to fill the area in that direction, but as some of these areas are much longer than others, while the difference in pressure is the same within and without the tuyeres in all directions, the penetration is either insufficient in some directions or too great in others.

For each diameter of hearth, number of tuyeres and general conditions as to blast-pressure, kind of cinder, etc., there is a given diameter of tuyeres which will throw the blast to the center sufficiently, without allowing great dead spaces on the walls between the tuyeres. If the tuyeres be made smaller than this, the force of the air-jet straight ahead will take an excess of blast to the center of the furnace and allow pilasters, so to speak, of dead material to form on the walls between the tuyeres, so reducing the active area of the hearth and making the furnace work too hot at the center. If, on the other hand, the size of the tuyeres be increased, the blast-jets fail to reach the center, but spread out laterally to such an extent that they may even cut the walls between the tuyeres, while a cone of dead material forms in the center.

One of the best furnace-men in the country once told me that he had banked his furnace, cut through the jacket, and put in additional tuyeres; that in cutting in for these they had found something like 3 ft. of perfectly dead material on the walls, and that after starting up they had made nearly 50 per cent more iron than the best they could do before. Naturally, he was a believer in multiple tuyeres, though not extreme in his views.

On the other hand many illustrations could be gathered in which the results were slight or even objectionable, under circumstances at first sight not very different.

The explanation is not difficult. In the first case the size of the tuyeres had probably been increased until they were as large as the blow-stocks and bustle-pipe connections could supply, and the velocity of the blast into the furnace could not be reduced by further increase in size of the tuyeres, although it was very much too high, with the blast all going up the center, and very heavy pilasters built up between the tuyeres on the bosh-walls, as shown by the depth of dead material cut through, before fire was reached.

When the increased number of tuyeres was put to work the velocity of the air-jets was diminished, and they were able to spread out laterally so as to melt off the pilasters, and increase the effective area of the hearth very materially. But if the bustle-pipe connections and tuyeres had been enlarged so that the proper quantity of air at the required temperature and pressure could have gone through them at the proper velocity, the results would have been in all probability almost if not quite as good as those attained by the use of a greater number of tuyeres.

If now, thinking to profit by this example, some furnace-man whose furnace was already equipped with a proper size of tuyeres, had followed a similar course, he would have so far reduced the velocity of the blast-jets that their penetration would have been insufficient; and they would have spread out sidewise, scouring the walls between the tuyeres and allowing a cone of cold material to form on the bottom in the center. In such a case, unless the area of the individual tuyeres had been reduced in proportion as their number was increased, the condemnation of multiple tuyeres would have been as hearty as its praise was in the first case.

It is not to be overlooked, however, that, other things being equal, the area of the pilasters on the walls varies nearly as the square of the distance between consecutive tuyeres or inversely as the square of the number of tuyeres. On the other hand, it must be remembered that the saving in hearth-area obtained by increasing the number of tuyeres increases much more slowly with each increase in their number, and that the difficulty and expense of maintenance of the tuyeres increases with each increase in their number. It is therefore not strange

that the best opinion tends more and more strongly to a moderate number of tuyeres.

Before leaving this subject, I wish to call attention to a simple means of determining the activity of the different portions of the tuyere-plane, which is, of course, a direct measure of the penetration, and therefore of the correctness of the nozzle area. This method consists in passing a $\frac{3}{4}$ -in. or $\frac{7}{8}$ -in. rod through one tuyere, and pushing it through the column of stock as quickly as possible, until it strikes the far side of the hearth, leaving it from twenty to fifty seconds, and quickly withdrawing it. The relative temperatures it has reached at different points will be a correct measure of the activity of the hearth at the corresponding points.

I am indebted to Mr. Austin Farrel of the Cleveland Cliffs Iron Company for this simple but effective expedient. When he told me of it three years ago, I believe it was very little known, though it has since come into use to some extent, but is probably still unknown to some who will be as glad to hear of it as I was.¹ The results shown by this test are sometimes surprising. I have seen a rod which had been put into a furnace, blown with about 11,000 cu. ft. of wind through six 6-in. tuyeres, come out almost dead black for 5 ft. in the center, and so nearly burnt in two at the noses of the tuyeres that it broke at those points when it hit the ground. (The tuyeres were 8 ft. from nose to nose.)

On the other hand, a reduction of the size of the tuyeres to 4 in., while it showed much better results on the rod and lowered the bottom of the furnace (which was high before), was succeeded after a few weeks by a considerably greater loss of tuyeres and coolers. This is believed to have been caused by the tops of the pilasters which formed on the bosh walls, making gutters, which led all the dripping iron and cinder down on top of the tuyeres and caused their more speedy destruction. The pilasters, of course, were formed by reason of the too great velocity and penetration of the blast jets, as before explained.

It seems very probable, therefore, that where furnaces have a small number of tuyeres, it is, on account of this secondary effect, unsafe to increase the penetration so much as to bring the test rod to a uniform temperature clear across the hearth. In furnaces with more tuyeres, the pilasters, in consequence of their smaller cross-section, do not extend so far up on the bosh walls, consequently this danger is much less serious. This is a point in favor of a larger number of tuyeres than six; but the necessity for this is now everywhere admitted, if large product be aimed at.

During the interval since this was written practice in regard to tuyeres has now settled down to a very moderate number of tuyeres for hearths even larger than were dreamed of at that time. Mr. H. A. Brassert has recently stated in a paper before the American Iron and Steel Institute, May, 1914, that furnaces with hearths as large as $16\frac{1}{2}$ ft. or 17 ft. in diameter gave as good results with ten tuyeres as with fifteen, a statement which, in view of his experience, is authoritative.

The formula for the drop in pressure quoted above has been quite extensively used by some furnacemen to obtain comparative figures for penetration under different conditions. Mr. E. B. Cook of Cleveland in particular has made a careful study of this matter and has been good enough to communicate the results to me. He has found that the pressure-drop for small hearths ranges in good practice from 0.5 lb. to 0.75 lb., and on large furnaces from 0.8 lb. to 1.2 lb., except on the furnaces with very large hearths above mentioned, in which the

¹Since writing the above, I have been informed by Mr. Frank Firmstone that this expedient has been described by French and German writers—in some cases, several decades ago.

figure is about 2 lb., a fact to which we shall refer later.

What is meant by penetration is not always easy to grasp at first sight. We think of the furnace as being filled with gas rather than as containing a violent current of gas, particularly in the hearth where the blast comes in horizontally and must quickly take a vertical direction. In order to make the state of things plainer we can conceive of a tube of glass, 6 in. in diameter, filled with broken coke, with say six jets of water coming into it near the top and flowing down through the coke under the influence of gravity.

Assume that the quantity of water per minute remains constant under all conditions and that first the nozzles of the jets are quite large so that the water flows into the tube with a very low velocity. We shall obviously have a condition such as I have tried to portray in Fig. 1, the current of water running principally down the sides of the tube and only reaching the center after it has travelled down a long way.

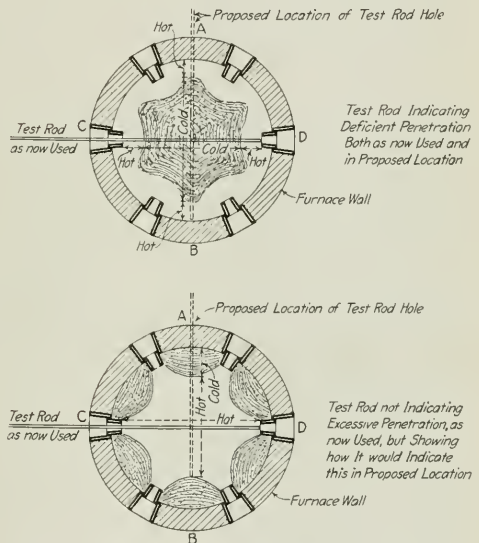
Imagine now that while the quantity of water remains the same, the jets are very much reduced in size so that their velocity is very great under the influence of a high pressure. We shall obviously have the condition shown in Fig. 2 in which the water is driven, in spite of the resistance of the coke, very largely to the center where the jets are stopped by impact upon one another. Here we shall have the greater portion of the water flowing down the center, and the sides not receiving their proportion for quite a distance down the tube.

Obviously now we can establish an intermediate condition in which the velocity of the jets is considerable but not excessive, as shown in Fig. 3. They are given sufficient energy so that by the time they reach the center the energy is all exhausted by the resistance of the broken coke, and there is no surplus to pile up the water in the center and cause a disproportionate flow in that portion of the tube. At the same time the velocity is sufficient to permit only that quantity of the water to flow down the space next the walls which is proportionate to the area of that region. These are precisely similar to the conditions of deficient, excessive and correct penetration in blast-furnace practice.

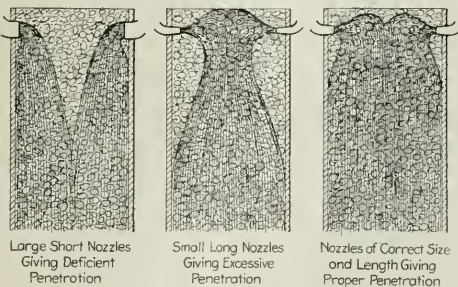
The penetration test in the quotation above given, in which the rod was absolutely black all over except for a couple of feet near the ends where it was white hot was made on a furnace with tuyeres very large in relation to their number and to the amount of blast blown; this furnace formed a huge "onion" of solid iron on the hearth which remained throughout the blast. The molten iron lay in the annular space between the onion and the crucible walls, and on account of the small area

of this space stood at a considerable height therein at cast time; when the furnace was cast the iron flowed with the greatest violence for one or two minutes and was then followed by the cinder, the cast being over. When the furnace was blown out this huge onion was found welded fast to the salamander, and rising some 2 ft. or more above the bottom of the hearth. There can be no possible doubt that this furnace worked continually with a cold center—a center column of stock which was not traversed by the gas, and which was only eaten away by a slow process of solution in the iron and cinder and stood like a cold poultice on the hearth. In subsequent blasts smaller tuyeres were used and the same conditions never arose again.

The operation of testing the penetration with an iron rod, described above as generally carried on, is rather unsatisfactory because no matter how excessive the supply of blast in the center may be it is obvious that there is no deficiency of blast supply near the walls in the space immediately in front of the tuyeres which the rod must traverse when the test is made through the tuy-



FIGS. 4 AND 5—LOCATION OF TEST ROD HOLES IN PENETRATION TESTS



FIGS. 1, 2 AND 3—CONSTANT QUANTITY OF WATER DISCHARGED THROUGH NOZZLES OF DIFFERENT SIZE INTO TUBES FILLED WITH BROKEN MATERIAL, ILLUSTRATING THE VARIATIONS IN BLAST PENETRATION

eres, the condition being somewhat as roughly indicated in Figs. 4 and 5, showing the condition in the tuyere zone of a furnace having six tuyeres with deficient and excessive penetration, respectively. Obviously the lines on which we should test are AB and not CD. This we can easily do, if there are cooling plates between the tuyeres and approximately on the level of the tuyere centers as there should be, by fitting the cooling plates half way between the tuyeres with a copper pipe, passing from the butt of the plate through into its nose, carefully screwed into the latter surface and pined over, the butt end of the cooling plate being caulked up against the copper pipe to make a tight joint.

This would give a water-cooled opening of sufficient size to admit a test rod and a penetration test made here would quickly show excessive penetration. These holes, of course, would be plugged with clay or could be closed with a screw plug, when not in use.

I have never tried this method of testing myself, but I see no reason to anticipate that it would not be per-

fectly successful, and it should certainly give much more accurate information than testing through the tuyeres.

The Blast Pressure Required to Overcome the Resistance of the Charge Column

This is obviously a subject not open to accurate mathematical investigation of the kind that Fleigner was good enough to make in order to supply the means for determining the pressure drop through the tuyeres. We can never hope for such a solution since from the nature of the case the conditions are not only of infinite variety but change from instant to instant, and the pressure required to blow a given furnace is something in which no rule has ever been suggested for even approximate guidance. Nevertheless this also follows a natural law, and in spite of the variation in the conditions is amenable to mathematical expression, the constant, of course, being derived entirely from practice.

Let us consider first the relative velocities of the gas column at different zones of the furnace as affected by its volume and by the area of the furnace at the corresponding zone. The three zones at which we have any knowledge are the tuyeres plane: the top of the bosh, where we assume that combustion to CO is complete and that the gas has given up heat generated by its combustion down to the critical temperature; and the stock line of the furnace. The volume of the gas is determined by three circumstances, its chemical condition, its absolute temperature, and its absolute pressure.

Let us assume that the tuyere pressure is 15.3 lb. or 30 lb. absolute, that the top pressure is 0.3 lb. or 15 lb. absolute, and that the pressure at the top of the bosh has dropped in the same proportion as the fraction of the total height traversed, let us say one-fifth to 12 lb. or 27 lb. absolute. Let us assume further that the blast temperature is 1200 deg. Fahr., and the top temperature 400 deg. Fahr., the critical temperature prevailing at the top of the bosh, as before stated, being 2750 deg. the absolute temperatures corresponding to these are 1660 deg., 860 deg. and 3210 deg. Let us further assume in accordance with average practice that the top gas contains 60 per cent nitrogen.

At the tuyere plane the blast obviously enters as air; at the top of the bosh the oxygen of the air has become CO which increases the gas volume, as compared with air, from 1 to 1.207. At the stock line the nitrogen which is the same in absolute amount has fallen from 79.3 per cent to 60 per cent, so that the total volume must have increased by chemical action, additions, etc., to 1.32. Multiplying together the results of these three conditions we find that the relative volume at the tuyeres is $1 \times 1660/30 = 55.4$; the volume at the top of the bosh is $1.207 \times 3210/27 = 143$, and the volume at the stock line is $1.32 \times 860/15 = 75.5$.

If the gas is to travel at a uniform velocity the area at these levels must be proportional to its absolute volume at these points, and in a circular column the diameter of the column must be proportional to the square root of these volumes. These square roots are: 7.46, 11.95 and 8.67. Multiplying all of these by a constant factor to bring them to recognizable dimensions they become 16.1, 25.6 and 18.6. These are not very far from the diameters at the tuyeres, the bosh and the stock line of a 90-ft. furnace though the bosh diameter is too large and the hearth a little small.

We see, therefore, that if the furnace were empty the gas column would pass through it at an approximately constant velocity from top to bottom; the same would also be true if the percentage of voids if all portions of the furnace was the same. It is impossible for us to assert that this is true but I am unable to perceive any reason why we should not expect that it is approx-

imately true since the variation around the top of the bosh is explained by changes in other conditions, as we shall presently see.

A heterogeneous mixture of materials of different sizes must, by mixing, reach a sort of irreducible minimum of voids depending on the size and kind of the materials. From the top of the bosh down to the tuyeres the coke is burned, and as the process is necessarily progressive the average sizes of the pieces at the tuyere zone must be much smaller than those at the top of the bosh which in a general way leads us to expect a proportional decrease of the voids, which would naturally necessitate a diameter of hearth larger than the gas volume alone would account for.

The materials other than coke which have existed as solids down to the top of the bosh are liquified as they pass below that zone with a considerable diminution of volume, and a much great diminution of their resistance to the passage of the blast on account of the closeness of their contact with the coke when in the liquid form, hence the available volume of voids is greater than in any other zone of the furnace either above or below and the area may be proportionally smaller than the gas column estimate would lead us to expect.

Considering these various conditions we may tentatively assume that the velocity of the gas column upward through the furnace is constant, though this is not necessary to the correctness of the formula for blast pressure, presently to be developed.

Turning now to the matter of the resistance to the passage of the gas offered by the stock column it will perhaps be as easy to approach it by the path I first followed as by any other.

A number of years ago there was an active controversy in one of the technical journals concerning formulas for the flow of compressed air in pipes. Numerous formulas were proposed and the results obtained by applying them to the same problem were truly startling. It finally reached the point where one correspondent declared that the initial pressure for a given flow in a long pipe line could be dropped from 160-lb. to 100-lb. gage pressure by the simple expedient of raising the terminal pressure of the air leaving the pipe line from atmospheric to 40-lb. pressure.

At this point I began to wonder if there might not be something wrong with the formula which all the parties were using in one shape or another, and with one set of constants or another. This formula was merely the mathematical expression of the statement that the friction of a fluid through a conduit is proportional to the length of the conduit, to the square of the velocity, to the wetted perimeter of the conduit, divided by its area, and to a coefficient depending on the liquid. This is a fundamental law and is absolutely correct, but a little consideration showed that when the air in the above example dropped from 180-lb. pressure absolute to 15 lb. absolute, its volume and therefore its velocity increased twelve times, and as the friction is by the law proportional to the square of the velocity the friction in this part of the pipe would obviously be 144 times as great per unit of length of pipe as in the high-pressure portion, except for the effect of the density.

To see what effect this consideration would have on the results I took one of the examples quoted and divided the length of pipe given into ten sections, figured the drop of the first section, then with the new velocity consequent on the increased volume due to the decreased pressure calculated the pressure drop for the second section, and so on, finally reaching a reasonable result. It presently became obvious that this was a legitimate field for a little calculus.

It is admitted that the friction of gases is proportional to their density, as it obviously should be, other things being the same, so we must introduce this factor into the fundamental law which may be expressed as a formula by putting

P_1 = the initial pressure absolute.

P_2 = the final pressure absolute.

L = length of the pipe.

D = the diameter of the pipe.

W = weight of air passing per minute.

S = density of air.

V = volume of free air per minute.

v = velocity in pipe per minute.

$$(\pi D) \left/ \left(\frac{\pi}{4} D^2 \right) \right. = 4/D = \text{wetted perimeter} \div \text{area.}$$

K is a constant to be determined by experiments; all constant factors are thrown into this and may be disregarded until the final equation is reached, proportionalities being treated as equations.

Then

$$V = W/S$$

and

$$v = V \left/ \left(\frac{\pi}{4} D^2 \right) \right. = W \left/ \left(\frac{\pi}{4} D^2 S \right) \right.$$

Then the fundamental law for a short section of pipe becomes

$$P_1 - P_2 = \frac{4kLSv^2}{D} = \frac{4kLS}{D} \times \frac{W^2}{(\pi/4)^2 D^2 S^2} = \frac{64kLW^2}{\pi SD^5}$$

but S is proportional to P and we can put

$$P_1 - P_2 = \frac{64kLW^2}{\pi D^5 \times (P_1 + P_2)/2}$$

For the very short length of pipe dL we have

$$P_1 - P_2 = dP \text{ and } (P_1 + P_2)/2 = P$$

so that we have

$$dP = \frac{64kW^2}{\pi D^5 P} dL \text{ or } PdP = \frac{64kW^2}{\pi D^5} dL$$

whence

$$P_1^2 - P_2^2 = K \frac{W^2 L}{D^5}$$

By applying the results of the extensive experiments on the flow of compressed air in pipes at the Mont Cenis tunnel I derived the necessary constant and the formula took the final form of

$$P_1^2 - P_2^2 = 0.0006 \frac{W^2 L}{D^5}$$

in which form it has been very widely used, and extensive experiments made in the natural gas lines have completely verified its correctness when the proper factor for the density of natural gas is used.*

I had made a number of attempts to understand the relations of changes in blast volume to changes in pressure on a given furnace, and also the relation between the pressure required for a given volume of blast on two furnaces of different sizes, but I had never been able to obtain any results at all in accordance with the facts. Gradually it began to seem that the same laws might be applied in this case as in the case of the friction in pipes. That is to say, it was a case of gaseous friction with all the consequence of changes in velocity due to changes in pressure, but with this important difference that the friction in case of the round conduit comes only from the perimeter of the pipe, whereas in a furnace shaft filled uniformly with solid material the ratio of surface to volume of interstices is the same over

the entire area, and therefore the factor for wetted perimeter is not needed.

Let us consider two furnaces of the same relative proportion, one, A, 50 ft. high by $12\frac{1}{2}$ ft. bosh diameter, of 4000 cu. ft. capacity and blown with 8000 cu. ft. of wind per minute. This would require, we know by experience, about $3\frac{1}{2}$ lb. pressure. The other, B, 100 ft. high by 25 ft. bosh diameter, of 32,000 cu. ft. capacity and blown with 64,000 cu. ft. of wind, what pressure will be required for it?

Let us assume that the two furnaces are each divided into fifty equal zones, those of A being similar to those of B, though only half as high. It is obviously reasonable to assume that the specific resistance of the stock to the passage of the gas will be the same in the corresponding zones; that is, that the ratio of interstices to surface of stock exposed will be the same in corresponding zones in each. Let us assume for the present that the shape of the furnaces is such that the velocity of the gas through them is constant in all zones, or if not, that it varies similarly in the two stacks so that this variation can be eliminated from consideration. This reduces the fluid friction of the gas current down to the same basis as that for flow in a uniform conduit.

Then proceeding as in the previous case we put

D = furnace diameter.

H = furnace height.

P_1 = absolute pressure at the tuyere zone.

P_2 = absolute pressure at the stock line.

W is the wind blown per minute measured under atmospheric conditions.

S = density of the air (proportion to the pressure when the temperature is the same).

W = velocity of gas through the furnace proportional

$$\text{to } \frac{W}{SD^2}$$

Proceeding as before we find for a short section dH that

$$dP = K \frac{W^2 S}{SD^5} \times dH = K \times \frac{W^2}{SD^5} \times dH$$

If we substitute P for S , to which it is proportional, we have

$$PdP = K \frac{W^2}{D^5} \times dH$$

and by integration

$$P_1^2 - P_2^2 = K \frac{W^2}{D^5} H$$

The constant K we determine from the pressure assumed from general experience in the case of the small furnace, and with this value of K we determine the pressure in the large furnace to be 19.4 pounds as follows:

For our small furnace, $P_1 = 18.5$, $P_2 = 15$, $W = 8000$, $H = 50$, and $D = 12\frac{1}{2}$, from which we can find K as follows:

$$(342 - 225) = K \frac{64,000,000 \times 50}{24,400} \text{ or } K = 0.00089$$

and for the large furnace using the same value of K we get

$$P_1^2 - 225 = 0.00089 \times \frac{64,000^2 \times 100}{390,625} = 1,050,000 \times 0.00089 = 935$$

$$P_1^2 = 225 + 935 = 1160, P_1 = 34.1 \text{ absolute} = 19.4 \text{ gage.}$$

It must be thoroughly understood that the value of K is derived entirely from experience. There is no known method by which we can even attempt to determine its value mathematically. We must therefore determine a value for it which will fit established practice reasonably well before we can safely use the formula or com-

*I subsequently found that this formula had been developed at least once and probably several times before, but apparently the earlier investigators did not take the trouble to determine the constant, without which the formula is practically valueless, and it had never come into general use.

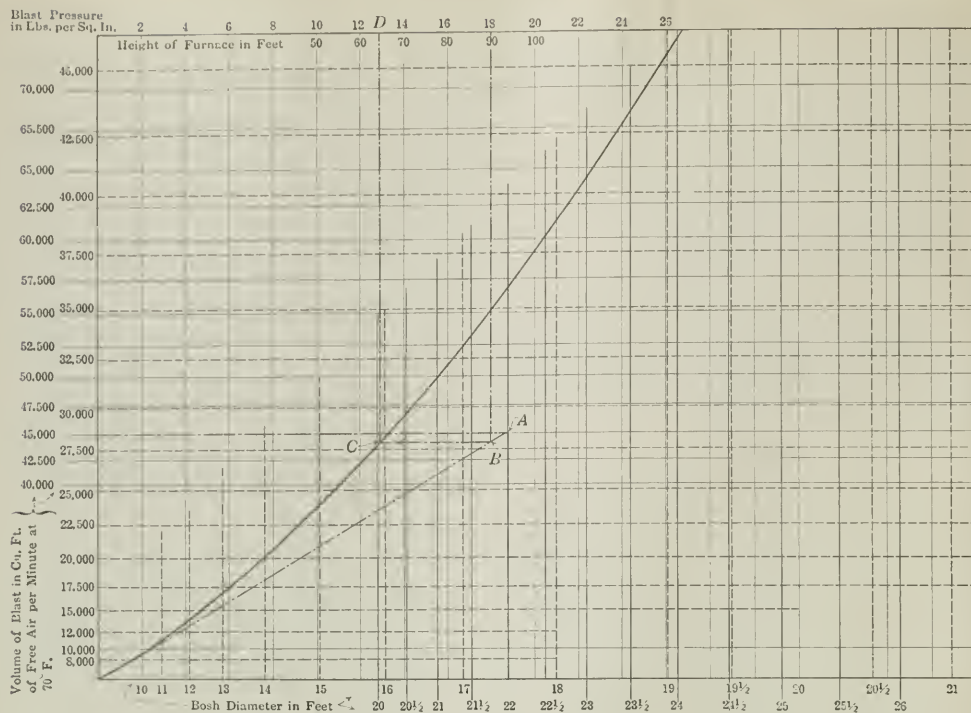


FIG. 6—BLAST-PRESSURE CHART

Instructions for Use of Blast Pressure Chart.—Note first of all that there are two rows of figures along the bottom giving bosh diameters, and two rows along the left-hand end giving blast volumes. The inside rows of these must always be used together, or the outside rows; never figure from the inside in one row and from the outside in the other row. Some of the figures are duplicated in the inside and outside rows. This is to extend the scale and flexibility of the chart. As long as the corresponding rows are used together it makes no difference which one is taken.

Take the vertical through the figure at the bottom giving the bosh diameter and the horizontal through the figure at the left giving the blast volume in cubic feet of piston displacement. From the intersection of these draw a diagonal through the origin and extend it until it cuts the vertical through the height of the furnace given just inside the cross-sectioned area of the diagram at the top. From this intersection draw a horizontal to the curve, and from the point of intersection draw a vertical to the top of the diagram and read the pressure in the figures along the top edge of the cross-sectioned area. For instance, find the normal working pressure of a furnace, 22 ft. bosh diameter by 90 ft. high, blown with 45,000 cu. ft. of wind piston displacement per minute. The vertical through 22 in the outside row intersects the horizontal through 45,000 in the outside row at the point A. Through this draw a diagonal toward the origin until it cuts the vertical through 90 ft. furnace height at B. From this draw a horizontal to its intersection with the curve at C, and from this draw a vertical to the point D at the top of the diagram, which shows a little less than 13 lb. pressure.

pare the pressure of different furnaces with its aid. By comparisons with actual results I reached the conclusion that the proper value of K was 0.00070, and in order to make the formula easy of application I prepared a diagram, shown at Fig. 6, with the aid of which, with the accompanying explanation for its use, problems involving furnace pressure may be solved in one minute.

Through the kindness of a number of furnacemen this formula has been checked against practice on a number of furnaces, with the result that I believe its indications are about a pound too low in the region of 15 lb. pressure, and it is probable that the value of K should be 0.0008. While there are variations, the correspondence between the results of this formula and the pressures actually found at furnaces of different sizes and operating under different conditions is very much closer than might be expected, so that I believe it may be safely assumed to be founded on correct hypotheses, and in the absence of knowledge based on practice to give a reasonably reliable indication of the actual pressure that may be expected under any given conditions.

It will be noted that this pressure includes both the stock column resistance and the tuyere pressure. It would be possible to subdivide it so as to give stock column resistance only, but this is not worth while for

two reasons: First, the variations of tuyere pressure drop are smaller than the normal variation in blast pressure. Second, the tuyere pressure drop increases with the size of the furnace, as stated above, so that its variation is roughly the same as that of the stock column pressure. It is therefore not worth while to differentiate them, but is simpler and is exact enough for all practical purposes to include both in the one formula.

The top pressure assumed for the chart is that of the normal atmosphere, 14.7 lb., on the basis that most of the furnaces in the country are located several hundred feet above tide level, and the actual atmospheric pressure is about enough lower than that at sea level to allow for the top pressure required to drive gas through the flues.

It should be noted that variations from this formula tend to be, to a certain extent, self-compensating. That is to say, if owing to any condition the pressure rises, this in turn increases the density, which reduces the velocity and thereby tends to keep down the pressure drop. This may be illustrated by the electrical resistance of the tungsten lamp as compared with the carbon. The resistance of carbon decreases with temperature, therefore a slight rise in voltage, driving more current

through the filament, heats it hotter, reduces its resistance and tends to let still more current pass, whereas with the tungsten lamp the resistance increases with temperature, so that an increase in voltage results in an increase in temperature, and this in turn in an increase in resistance, thereby tending to cut down the increased flow of current and reduce the variation due to its effect. As a result tungsten lamps show much smaller variations of luminosity with a given variation in voltage than do carbon lamps under the same conditions. So owing to the nature of gaseous friction variations in blast pressure are much smaller than they might be expected to be.

This fact probably has something to do with the comparative correctness of the blast-pressure chart over wide variations in conditions.

It should be clearly understood that the pressure given by this formula is only the normal working pressure. The furnace may get into a condition in which the gas blows through easily, due, perhaps, to a scaffold on one side above and another on the opposite side below, or something of that kind, and in such comparatively rare cases the actual pressure will be lower than that shown by the chart.

On the other hand, very many causes may make the furnace work with a considerably higher pressure than that given by the formula; there is, in fact, no limit in this direction except the power of the engines. First, the furnace may form a ring scaffold which forces all the gas to go through a sort of nozzle much smaller than the diameter of the furnace, and consequently with a much increased velocity and resistance. Second, the slag may become tough and stringy, and therefore be blown by the blast into the interstices of the coke, greatly obstructing them instead of running in quiet trickles down over the surface. Third, the hearth and bosh in case of serious trouble may become almost frozen solid, with the result that only very small passageways are left through which the blast can find its way, and the slag in those is excessively tough and stringy. Fourth, and probably most common of all, the deposition of carbon (described in the article on chemical principles), which is sometimes extremely voluminous, in cases amounting to several times the bulk of the ore, may be deposited in the interstices of the stock in such quantity as to greatly obstruct the flow of the gas. These are all conditions which we have difficulty in proving; to measure them quantitatively is, of course, inconceivable. We cannot therefore hope to fit a formula to these diverse variations.

Leaving abnormal conditions to one side it has been found at a number of plants that the formula coincides with the results of normal-working furnaces with a degree of accuracy which is fairly satisfactory in so approximate a matter, though, as before stated, it is perhaps a little low. It should be stated that the quantity of air given on the chart is that measured by piston displacement in normal practice. This is indefinite to a certain degree, but unfortunately we have nothing else, and with the great improvements of blowing engines which have occurred in recent years this is sufficiently accurate for our purpose. It is probable that the actual air corresponding is less by about 12 per cent under the ordinary conditions of good practice.

It will be noted that this formula takes no account of difference in the condition of the ore, which varies from the fine sand of the Mesabi to the all-lump ore of Southern practice. There is probably a slight variation due to this cause, but owing to the self-compensating nature of the action described above, it is very much less important than might be expected, or at least the formula fits furnaces under Southern conditions

about as well as it does those running on Lake ore, which means generally from 50 to 90 per cent Mesabi.

It is greatly to be hoped that all interested will apply this formula to their conditions, and if they will communicate the results of such application to the editor of this journal, with as full a description as possible of the conditions, it will promote the collection of data which will either put this formula on a firm foundation or upset it altogether. It is presented here because of the absolute lack of any other means of reaching the desired end, and because the results of its application were found to coincide so much more broadly with practice than was expected when the formula was developed.

The Effects of Blast Pressure

The pressure of the blast tends to retard and make more difficult the descent of the stock. It is curious that this idea is not more generally held (a few years ago it was almost entirely ignored), but on the basis of Newton's first law of motion, that "action and reaction are always equal and in opposite directions," it seems impossible to escape the conclusion that if the stock column resists the ascent of the blast at the rate of so many pounds per square inch, then necessarily the ascent of the blast resists the descent of the stock by an equal number of pounds per square inch.

This view has not always been admitted from the theoretical side, but practically it has been recognized by the century-old practice of slacking the blast when the charge column was "hung" and refused to settle properly.

From this consideration it is very evident that to secure free and regular settling of the charge one of the prime conditions is to have the blast pressure low in relation to the weight of the charge column, and this, with the great expense involved in compressing the blast to a higher pressure than is absolutely necessary, would lead us to believe that high pressure was an unmitigated evil, and that in general the lower the pressure with which a furnace will work, the more satisfactory its work will be. But while this is a fundamental consideration, and should be the controlling one, there is another condition brought about by high pressure which is worthy of careful consideration, as first pointed out to me by George G. Crawford. This consideration is that the velocity of combustion is greatly augmented by pressure, and as most modern furnaces are driven to the limit set by their ability to burn the carbon in the space available for that operation this is a consideration not lightly to be neglected. Moreover, quick combustion means a decided localization of the zone of highest temperature, which in turn means lowering the zone of fusion and bringing more closely under control that region of the furnace at which scaffolding due to pastiness is likely to arise.

The standardization of bomb calorimeters is the title of Circular No. 11, issued by the Bureau of Standards. The paper describes briefly the methods of calibrating and using bomb calorimeters. Provision is made by the Bureau for distributing standard samples of pure materials, such as sugar, naphthalene and benzoic acid, for the purpose of standardizing calorimeters and securing uniformity in heat tests.

The Haynes Stellite Company of Kokomo, Ind., has placed a contract with the Snyder Electric Furnace Company, Chicago, for a 1½-ton per 24-hr. electric melting furnace which has a one-eighth-ton holding capacity, 50 kw. input and will produce 12 heats per 24 hr. The Haynes Stellite Company is the manufacturer of the cutting alloy "stellite."

The Safe Transportation of Explosives and Other Dangerous Articles*

BY COL. JAMES L. TAYLOR

Before the organization of the Bureau of Explosives, as it is commonly called, this important matter was regulated through the local regulations of the railways, and, as might have been expected, such regulation was often found to fail of its purpose in the particulars of that standardization and uniformity so indispensable to the enforcement of regulations which instituted or attempted to institute departures from the prevailing methods of competition and of practices that had previously been permitted to exist. The consequences of these conditions were in too many instances disastrous, and the progress toward their amelioration was of a very slow and disappointing character until the organization of the Bureau of Explosives was effected and its regulations put into force by practically all of the railways embraced in the organization of the American Railway Association.

Following this condition as a natural sequence, it was finally adjudged necessary to have the matter placed in the category of federal control, and by appropriate legislation to make the enforcement of the regulations one of universal and standard requirement. And so on May 30, 1908, the President of the United States approved an act of Congress under the title, "An act to promote the safe transportation of explosives and other dangerous articles and to provide penalties for its violation." The Interstate Commerce Commission was made that branch of the government to whom was entrusted the fixing and promulgation of the regulations to make the act effective within ninety days after its passage. Well within the limit of that period the regulations were duly promulgated, which in the language of the act were to be "the best known practicable regulation" for the purposes of the act, and which, in fact, were in a large degree the regulations of the American Railway Association, with some modifications which time and experience had demonstrated as necessary. They were issued in the name of and by the authority of the commission as the regulations to govern the transportation of the articles referred to.

On March 4, 1909, the foregoing act of Congress was repealed and the date of such repeal was to be on Jan. 1, 1910, and the title of the repealing act is a very suggestive one, for it is entitled "An act to codify, revise and amend the penal laws of the United States, to take effect and to be in force on and after Jan. 1, 1910." From that date to the present the legislative regulation of this matter has been one of federal law. The sections of this act last named, which apply more especially to the subject of our consideration at this time, are included in Sections 232 to 236 inclusive. As the first three are practically the first act in its essence, I will not repeat them. Sections 235 and 236, however, I will repeat, as they stand upon the record of the law books to-day, and have stood there since Jan. 1, 1910:

Section 235. Every package containing explosives or other dangerous articles when presented to a common carrier for shipment shall have plainly marked on the outside thereof the contents thereof; and it shall be unlawful for any person to deliver, or cause to be delivered, to any common carrier engaged in interstate or foreign commerce by land or water, for interstate or foreign transportation, or to carry upon any vessel or vehicle engaged in interstate or foreign transportation, any explosive, or other dangerous article, under any false or deceptive marking, description, invoice, shipping order, or other declaration, or with-

out informing the agent of such carrier of the true character thereof, at or before the time such delivery or carriage is made. Whoever shall knowingly violate, or cause to be violated, any provision of this section, or of the three sections last preceding, or any regulations made by the Interstate Commerce Commission in pursuance thereof, shall be fined not more than \$2,000, or imprisoned not more than eighteen months, or both.

Section 236. When the death or bodily injury of any person is caused by the explosion of any article named in the four sections last preceding, while the same is being placed upon any vessel or vehicle to be transported in violation thereof, or while the same is being so transported, or while the same is being removed from such vessel or vehicle, the person knowingly placing, or aiding or permitting the placing, of such articles upon any such vessels or vehicle, to be so transported, shall be imprisoned not more than ten years.

These are the requirements of the law which must be complied with, and a full understanding of the law is requisite which must be had by every person in any way brought into connection with the transportation of these dangerous articles.

The "other dangerous articles" (besides explosives) are chiefly inflammable gases, inflammable solids or oxidizing materials, acids or corrosive liquids, compressed non-inflammable gases, etc.

Probably the most important feature is the safeguarding of these dangerous articles by the security of their packing. And I am happy to state that in this respect the Bureau for the Safe Transportation of Explosives and Other Dangerous Articles has achieved a notable success in securing, after a somewhat prolonged effort, the full support of the manufacturers and shippers of acids, charcoal, friction matches, compressed gases and other articles of chemical industry, most of whom have co-operated with us by giving us the full benefit of their experience, especially in the matter of formulating suitable rules for transportation.

In a similar way, too, we have secured in a very large degree the co-operation of the manufacturers of shipping containers for these classes of dangerous articles, especially in railway transportation.

It is well known that there is no well-defined limit to the forces that may act upon the shipping containers which include the crushing weight of other packages piled upon them; the shifting of freight in the cars incident to transportation conditions; the failure of many types of boxes of various kinds to carry the load of other packages; the proper resistance to the shocks incident to the handling of cars, and the proper methods to resist the force of such shocks, by a proper cushioning of containers to resist them, as well as the high pressures slowly applied.

In this connection I would refer to a series of monographs upon this subject: The lectures of Col. B. W. Dunn, late of the Ordnance Department of the United States Army, who is the chief inspector of the Bureau of Explosives of the American Railway Association, delivered upon many occasions, among which were the lectures at the twenty-fifth semi-annual convention of the National Association of Box Manufacturers, at Detroit, Aug. 28-30, 1912; the address at the first annual convention of Manufacturers of Corrugated Fiber Containers, held in Atlantic City, July 7-9, 1914, and finally, and perhaps the most important of all in the profitable character of the information which it gave, the address of Colonel Dunn which appears in the Proceedings of the New York Railroad Club at its meeting April 15, 1910, under the title "Stresses Developed by Collisions of Freight Cars."

Abrasive Materials.—The production of abrasive materials in 1914 is given in Bulletin II:29 of the Geological Survey.

*Synopsis of a lecture delivered before the First National Exposition of Chemical Industries, New York City, on Sept. 23, 1915. The author is assistant to the chief inspector of the Bureau of Explosives of the American Railway Association. The address was illustrated by numerous stereopticon views.

The Barium Industry in the United States Since the European War*

BY MAXIMILIAN TOCH

Within the last eighteen years there have been three attempts to establish a barium industry in the United States prior to Aug. 1, 1914, and all three of them have been unfortunate failures. I have investigated the cause of these failures and I find that two of them failed through financial and chemical mismanagement, while the third was utterly destroyed on account of its inability to compete against foreign competition.

I have been identified with the manufacture of barium products for nineteen years, and while the venture of my firm has been successful it was never very large and was confined to one particular barium salt, which sold entirely on account of its quality.

A well-known and successful chemical corporation manufactured barium chloride and barium sulphate in New York City a little over fifteen years and made very good products. As soon as they turned out reasonable quantities some foreign chemical manufacturers undersold them at such a price that they found they were unable to continue, and as soon as they were put out of business the foreigners raised their price. They have kept the trade ever since, for they have taught the American manufacturer the unfortunate lesson that if he were to establish an industry he could not continue it successfully, for the well-known methods of "dumping" large quantities on this market in addition to the meager tariff would soon teach them that they had better not try to make American goods again.

I believe I was the first one who pointed out to the Department of Commerce the shortcoming of our own laws. If a manufacturer in this country attempts to put a competitor out of business by what is known as unfair methods, all one has to do is to file a complaint with the Federal Trade Commission, and the matter is considered at once by its examiners and attorneys. But it is quite obvious that any law made in this country has no sanction against a foreign corporation outside of the jurisdiction of the United States any more than a firm in the United States can be held responsible for its actions according to the law of England, France or Germany.

Two weeks after the great war in Europe was under full swing, my firm recognized that a very interesting portion of its business would be obliterated if we could



PLANT OF DUREX CHEMICAL WORKS AT SWEETWATER, TENN.

not obtain barium compounds, and, to be exact, on the 14th of August, I started negotiations for a plant at Sweetwater, Tenn., for the purchase of a large tract of land containing the mineral barite, and in October, just a year ago, the first carload of barium salts was shipped from Sweetwater, Tenn., to our Long Island City works. From that day to this the plant has been working night and day. Additional mines have been purchased, additional installation has been erected, and the corporation is destined to continue to grow provided our own parsimonious and short-sighted Government will not aid in its final destruction.

There has been a great deal of talk about the dye industry in the United States, and any number of capitalists would invest the necessary funds to-morrow to establish a permanent aniline industry in the United States if they had some kind of assurance that the laws which prohibit unfair competition among ourselves could in some manner be made active as against those outside of the United States. There has been a tremendous amount of talk with reference to enacting an "anti-dumping" law. For months this has gone on, and up to now it is simply nothing but talk. A great deal of publicity has been given by public officials about the new and wonderful methods and short cuts that have been discovered for the manufacture of aniline dyes out of soft coal to such an extent that it has made the finest and best method for stock jobbing that has ever existed, but there isn't a color maker in the United States who can buy for immediate delivery the necessary aniline colors for the manufacture of the lake colors in any reasonable quantity in spite of all this caloric atmospheric discussion.

The barium industry in the United States is not an industry that can be started over night, and among the failures that I referred to, one of them was due to the fact that theory took the place of practice. The starting point of the barium industry in the United States is the admixture of barium sulphate and coal, both of which are finely divided, and heated, when the coal converts the entire oxygen into carbon dioxide, and leaves barium sulphide behind. The best that any man can do in practice is to get 70 to 75 per cent reaction. In our works we have had runs where we have gone as high as 85, but I think this is purely accidental, yet theoretically the reaction ought to be complete; and the difference between theoretical chemistry and chemical engineering shows that the chemical engineer must devise apparatus which will fit his raw material.



PILE OF ORE OUTSIDE FACTORY

*A paper read before the New York Section of the American Chemical Society, Chemists Club, October 8, 1915.

Not all barite is suitable for reduction. I have seen disastrous results where calcium fluoride was contained in the barite, and where certain forms of iron would actually produce a paralysis in the reaction, and if up to now I have had a slight measure of success in the manufacture of these compounds it is because I had a knowledge of the manufacture of these compounds prior to the European war.

Chemical engineering is 49 per cent chemistry and 51 per cent business acumen. I place the business end ahead of the chemical end for the obvious reason that ability to finance, ability to sell at a profit, and ability to organize are ahead of the chemical reactions involved. You can buy chemical talent, but you cannot buy business efficiency. You can buy barytes of any kind, but you cannot buy in the open market the skill necessary to design this apparatus so that the results will be uniform. I have seen a chemical industry fail because no commercial method of water purification necessary for the reaction was at hand, and if the subject had been carefully studied in advance a fortune could have been saved.

There are many arguments in favor of protection of the chemical industries in the United States, and what I say about the barium industry might refer practically to any other chemical industry, for we have economic differences between Europe and America which cannot be neutralized excepting by a system of protection in addition to an "anti-dumping" law. The freight rate from Tennessee to the coast on our raw material is about \$4.50 per ton. That is to say, barite cannot be shipped for less than that except by rail and water, which is a purely theoretical rate, for under existing circumstances a fifty-ton car of barium ore cannot be transferred to a steamer unless the material is packed in sacks or barrels. The same material pays \$1.80 freight from Bremen to New York, and I have it on very good authority that the rate from the mines of Germany to New York is \$2 per ton, because the German Government has always fostered its commerce by making special freight rates to export shippers.

The railroads in this country, which are, of course, all privately owned, show that they cannot carry trade for less than a fixed sum owing to their overhead charges; but their overhead charges, which start with the interest on their watered stock, are so great that the shipper must suffer. An eight-hundred-mile haul from Tennessee to New York pays \$5 per ton, and a twelve-hundred-mile haul from Missouri to New York pays \$4 per ton, and the one railroad can afford to do it and the other railroad cannot afford to do it. If the unsuspecting public is forced to support an overburdened railway, the Government should at least equalize this matter by giving us a protection in the form of tariff.

It is very amusing to read in the papers almost daily about wonderful new methods and new corporations who are about to manufacture all the dyestuffs in the United States and that the shortage of dyes and chemicals necessary for dyeing is about to disappear. It seems to be a pity that any Government employee will lend himself to the exploitation of what looks like stock jobbing schemes without due investigation, for I have not been able to buy any American dyes, and no one else that I know of has been able to buy any American dyes such as are generally used for the manufacture of lake colors. On the same sheet of the daily press in which these forthcoming industries are heralded you could invariably find a news item stating that the dye works are practically shut down for want of even simple dyes.

It is at once amusing and pitiable to note the super-

ficiality with which these investigations have been conducted. Some weeks ago in the *New York Times* there appeared a statement that a corporation was formed and very shortly there would be no dearth of the barium chemicals necessary for the manufacture of mordants and paper glazing material, and that a great deal of credit should be given to this concern as being the first concern to manufacture the barium chemicals in the United States, and this just exactly one year after the industry with which I am connected had been steadily turning out hundreds of carloads.

It may be true that I have not trumpeted from the housetops that the concern which we started was supplying material with great regularity and of chemical uniformity, and our own Government did not know it. On the other hand, last Spring a friend of mine sent me a clipping from the German commercial reports giving a full description of the materials that we are making, and an item concerning myself, for the investigator had stated that many German chemists would recognize my name as having been president of a section of the Eighth International Congress of Applied Chemistry. This was last Spring, and now our own wide-awake Government is noting the fact that soon there will be a barium industry started in the United States.

One of the very serious drawbacks concerning the new barium industry in the United States is the inability to obtain raw materials and equipment. There isn't a steel factory in the United States that is not working overtime at high prices on appliances which are designed to kill people, and as long as this condition obtains we peaceful manufacturers who want new rotaries and new apparatus will simply have to abide our time and pay exorbitant prices until we can obtain parts of new equipment.

To give you a striking example, we needed in one of our works a set of bevel gears made of a special metal, and after waiting twelve weeks, because there was no shop in the country which would pay any attention to



TYPICAL BARITE MINE SHOWING CHUNKS OF PROJECTING BARITE ORE

us, we finally had to devise gears ourselves as a make-shift. Nor does this apply to machinery alone, for no one could take any contract on any of the barium salts like the chloride, nitrate or sulphate and hope to deliver any part, because it is absolutely out of the question to obtain acids. The people with whom we have dealt for our acids for years are simply either refusing to give us any materials or supplying us with ridiculously small lots at enormous prices, for there are other channels which buy larger quantities and pay more than the peaceful manufacturer can afford.

I mentioned before that industrial chemistry was 51 per cent business and 49 per cent chemistry, and these figures will serve for an example. I was often asked why we located at Sweetwater, Tenn., and while I did not have very much time to look around I found that that was the logical and strategic location for coal, labor, water, and ore, for all of these materials combined are perhaps more reasonable at that locality than anywhere else I know of. In order to make a success of this enterprise the works should be located within such a radius of the mine that the ore can be delivered at a reasonable rate.

The great and only question with reference to the barium industry is whether this industry shall live after the European war is over, and I could not answer that categorically without some explanation. It depends entirely upon our own Government. If on account of the economic conditions which I have described, foreigners will be prevented from underselling us, we will be able to live.

Our own manufacturers should get together and understand that the underlying principle of successful business is to have a profitable business, for no argument is necessary on this point other than to prove that when you have a growing and going manufacturing concern, in order to have peace and success, you must be able to pay your men a living wage, and you must be able to pay them regularly, for the shutdown of any works in any community, particularly in a small one, produces disastrous results. Innocent women and children are made to suffer through it, so that in the greed of obtaining business manufacturers must understand that cut-throat methods lead to bad results for all parties concerned. I hope that when this war is over, the barium industry will be firmly established and protected, as the economic conditions in this country would demand.

What a remarkable difference there is between the enterprise in Japan as compared to the United States. Japan has suffered with a lack of chemicals and dye-stuffs just as much as we have, and both Houses of the Japanese Government have voted to subsidize all corporations and firms who are about to engage in the manufacture of chemicals and dye-stuffs that were not formerly made in Japan to the extent of three and one-half million dollars, the other half to be subscribed by the manufacturers themselves. It is understood that the subsidy granted is for ten years in order that the new manufacturing concerns may pay a dividend of at least 8 per cent. In addition to this it is understood that the Japanese Government has protected these manufacturers in the form of a high tariff. And that is the country to whom we have been sending missionaries in order to convert them from their archaic beliefs.

It seems to me that it is a great pity that nothing has been done up to now to protect the American manufacturer, for a subsidy from the Government is out of all reason, even though this is at present the richest Government in the world and Japan rated as one of the poorest. As I said before, we can only hope to succeed if our Government will help us from being destroyed by outside influences.

Theories of the Flotation Process

In METALLURGICAL AND CHEMICAL ENGINEERING, Sept. 1, 1915, page 571, we presented a complete description of the Callow pneumatic flotation process, giving flow sheet and several illustrations of actual operations. Since that time Mr. J. M. CALLOW has presented further operating data and certain theoretical considerations, embodied in a paper read by him at a meeting of the Utah section of the A. I. M. E., Salt Lake City, from which we excerpt the following:

Theories

So far no satisfactory explanation of flotation phenomena has been advanced. At my instigation and under my direction, a large amount of research work has been done in an endeavor to formulate some logical explanation of the phenomena, and perhaps to find some scientific way of conducting flotation experiments in place of the empirical methods now in vogue. Although the latter object has not yet been attained, still these experiments have resulted in the formulation of a theory that appears to be well grounded and that may prove of interest and value to others engaged in this art.

Much work has been done at the Mellon Institute at Pittsburgh under the direction of Dr. Raymond C. Bacon, and lately by James A. Block at the station of the U. S. Bureau of Mines in Salt Lake City. The result of all of this work is summed up in the following statement:

In considering the connection between flotation phenomena and the physical properties of the minerals concerned, there are two parallelisms:

1. It has been noticed for some time that the minerals which floated were not easily wetted by water, while those which were easily wetted did not tend to come up with the froth. This is the basis of about the only theory so far widely circulated; it was well stated by Hoover in his book, *Concentrating Ores by Flotation*.

2. There is a parallelism between certain electrostatic characteristics and the flotation properties of ores.

In the first-mentioned theory, surface tensions and contact angles should be considered. Certain minerals, such as galena, will float on the surface of still water, while gangue particles, since they possess a greater adhesive attraction for the water than the water's cohesive attraction for itself, will be drawn through the surface film into the interior, and sink because of their greater specific gravity. These properties of floatable minerals and gangues are increased by the presence of oil and acid. Oil sticks to galena with greater tenacity than it does to silica, and an oil surface is still less easily wetted than a galena surface. The acid in the water causes a still greater difference in the various surface tensions. This, it seems, is without question the explanation of the action in the MacQuisten process, in which the ore particles are lifted to the surface, where they can be removed by skimming off the surface layer of the liquid.

With reference to the second parallelism, it has been noticed that extremely small amounts of certain colloidal impurities, such as saponin or tannin, were detrimental to flotation; while others, such as Congo red and methylene blue, did not interfere, and were, if anything, beneficial. In classifying these, the injurious ones generally came under the head of what physical chemists call electronegative colloids, while electropositive colloids were not harmful. Suspended particles will generally migrate when placed in an electric field, and this classification comes naturally from the direction of their migration. This migration is called electrophoresis, or electrical endosmosis, and is the result of the formation of contact layers around the particles by the liquid

containing them, very similar to the formation of surface films when liquids come in contact with air. These contact films almost invariably have a difference of potential between their inner and outer surfaces. An air-water contact film has, for instance, a difference of 0.055 volts, and other contact films have similar charges. This causes the particles to act like charged solids, and to be attracted by electric charges of opposite sign.

The charges on solids and non-miscible liquids can be conveniently studied on the stage of a microscope.

This work naturally led to the study of the charges exhibited by various ores and minerals, and in that work an interesting parallelism was observed, namely, that floatable minerals seemed to have positive charges, and non-floatable gangues negative charges. Some gangues were found with positive charges, but they were characteristically hard to handle, having a tendency to come up with the froth. These charges sometimes vary with the acidity or alkalinity of the liquid, and this variation is not inconsistent with the effects of acidity or alkalinity on the flotation of ores.

It has been noticed that these electrostatic properties depend on the condition of the surface of the particle and not upon the composition of the mass. For instance, lead oxide which is ordinarily negative, or neutral, when covered with a sulphide coating, takes upon itself a positive charge.

Recent investigations on the coagulation and deflocculation of slimes, on the coagulation and dispersion of colloids, and along similar lines, show that these contact film charges, although small, have an important bearing on the dispersion or coherence of particles suspended in liquid mediums. In fine suspensions and in colloidal solutions, these charges may often be neutralized by the introduction of oppositely charged ions, precipitation generally taking place whenever these charges fall below certain limits. Oppositely charged contact films have a general tendency to coalesce, while similarly charged films, if their charges are great enough to overcome natural cohesiveness, do not seem to coalesce, but to repel each other, and if the weight of the particles is small enough in relation to their size and surface, permanent dispersion will take place, the particles distributing themselves through a liquid in much the same manner that gas will fill a container.

In view of the above observations, it seems possible that flotation is the result of difference in polarity in the charges on the various ore particles, and on the bubbles. Since oil contact films and air contact films have both been proved to have negative charges, the positively charged minerals will adhere to either. The bubble mantles in a flotation machine are undoubtedly composed of oil, or of oil in emulsion, since pure water alone will not froth. The same forces, then, that cause oppositely charged colloids to agglomerate and precipitate, cause the minerals to adhere to the oil-covered bubbles, and the same forces that keep the particles of an oil emulsion dispersed, keep the gangue particles repelled from the bubbles.

Expressed briefly, the theory is as follows:

That oil flotation is an electrostatic process. It is a scientific fact that when a solid particle is suspended in water, the water will form around the particle a contact film which generally possesses an electric charge, the amount and polarity depending upon the nature of the surface of the particle and the electrolyte in which it is suspended. The presence of these charges can be demonstrated by the fact that the particles possessing them will migrate when placed in an electric field. It has been demonstrated that floatable particles have charges of one polarity (positive), and that non-floatable particles have charges of the opposite polarity (nega-

tive); that the froth is charged negatively and so attracts the positively charged or floatable minerals, and repels the negatively charged or non-floatable ones. It is this, it is believed, that causes the floatable minerals, galena, sphalerite, etc., to adhere to the froth, and the gangue minerals, silica, etc., to remain in the liquid where they can be discharged as tailing.

In the discussion which followed Mr. Callow's paper Mr. JAMES A. BLOCK said that during the last few months he has tested about fifty samples of ores, etc., the flotation characteristics of which he knew. Some of these were samples of froth and tailings from plants in actual operation, but most of them were samples taken from laboratory tests going on at the plant of the General Engineering Company, and at the station of the U. S. Bureau of Mines, Salt Lake City. In all of these experiments, no real exception to the theory was found. All of the tailing samples produced in actual flotation showed a negative polarity; all of the ores with the so-called "bad gangues," except one or two, showed some positive polarity, and these exceptions could be explained by the extreme dryness and scaliness of the gangue minerals, and all of the froth products showed positive polarity when the samples were fresh. It was often true that after standing some time these froth samples would reverse, especially when they contained considerable oil, but this reversal can be explained if we assume that the oil forms a coating around the particles upon standing.

The question might naturally be asked, "Can these electric charges be put to any practical use?" A machine used to purify clays employs very similar charges on the constituent particles of clay. This machine (see Fig. 1) consists of a revolving cylinder, made of conducting material, such as iron, about half immersed in a clay pulp in a trough. At a distance of about $\frac{1}{2}$ in. from the immersed side of the cylinder is a coarse wire screen. A direct current of about 50 volts was applied to the cylinder and the screen, the cylinder being the anode and the screen the cathode. The cylinder attracted the negatively charged kaolin, while the screen attracted the positively charged pyrite, ferric hydroxide, and aluminium hydroxide. It was found that a product running only about 17 to 20 per cent moisture could be scraped off the upper side of the cylinder, which revolved slowly, while the impurities fell through the screen to the bottom of the trough.

The objection to the process was the high cost of the power needed, which averaged over 30 cents per ton of product, but the process is undoubtedly of interest in that it shows that these electrostatic charges are de-

⁴Transactions of the English Ceramic Society, vol. X11, pp. 36 to 64 (1912-13).

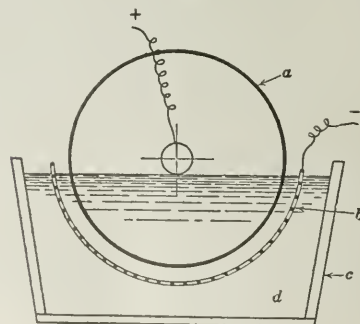


FIG. 1—APPARATUS USED IN PURIFYING CLAYS

a. Revolving cylinder. b. Wire screen. c. Wood trough. d. Clay pulp.

pendable enough to be put to practical uses. It is also of interest in that the polarity of the charges noticed on various minerals checks the results of the experimental work upon which the theory is based.

Mr. OLIVER C. RALSTON of the Bureau of Mines (Salt Lake City Station) said that for some time he had had a growing conviction that possibly the particles dealt with in the flotation of sulphide minerals were acting according to certain laws laid down in colloid chemistry. One of the characteristic things about either suspension or emulsion colloids is that their individual particles are charged with one or the other sign of static electricity. It is known that the amount and signs of these charges can be controlled by the amount and character of electrolytes put into the water in which the colloids are dispersed, and in turn the properties of the colloidal suspension are greatly changed with this change in the electric charges on the particles. The question has been whether the comparatively coarse suspensions of ore can be compared with suspension colloids, or whether they were too coarse to allow the electric charges on the suspended particles of mineral to produce any measurable effect.

"This question has been answered fairly definitely in my laboratory during the past year, for it was found that the electric charges on the particles of what we call 'slimes' and 'fines' are of considerable importance in the control of the rate of settling of such slimes in water. With this much definitely settled, and with a great amount of literature available in the realm of colloid chemistry dealing with the electric charges on particles of such things as quartz, galena and sphalerite, and on oil droplets and air bubbles, it was easy to find a combination of circumstances which might explain flotation from this new viewpoint. At about this time George W. Riter made the prediction that the depths of electrostatics would have to be thoroughly sounded before flotation phenomena could be entirely understood. He seemed to have the idea at that time that the charges on the particles were generated by friction in the flotation machine, in much the same way that a piece of sealing wax becomes charged when rubbed with flannel; but we know from colloid chemistry that these charges of electricity arise whenever two substances of unlike dielectric constants come into contact.

"Further work along the line of controlling the charges of the ore particles, thereby controlling the rate of settling of the particles in water, has convinced me that the charges are of considerable importance, and the results of this work will be reported soon. Mr. Callow told me last spring that he had much the same conception of the matter as I, and had the Mellon Institute in Pittsburgh working on it for some time. Mr. Callow sent a man to the Salt Lake laboratory of the U. S. Bureau of Mines to try out some methods of measurement which I had proposed and which had not been used in Pittsburgh; some of the results are presented in Mr. Callow's paper.

"The knowledge that when flotation conditions are good the froth has a positive charge and the rejected gangue a negative charge, that the oil droplets and the air bubbles are negatively charged, and the sulphide particles positively charged, is highly interesting. We have here electrical effects which are parallel to flotation phenomena, and the conclusion that they are connected with each other seems justifiable. Just exactly how they are connected is not yet clear and may prove difficult of solution.

"It is to be hoped that further work will be done along this line in order that a theory of flotation may be found, which will afford a more rational control of flotation testing, and an extension of the process to the treatment of any kind of minerals."

Radium from Carnotite

On the evening of Friday, Dec. 17, Dr. Charles L. Parsons, chief of the Division of Mineral Technology of the Bureau of Mines, lectured at a meeting of the New York Section of the Society of Chemical Industry on "Extraction and Recovery of Radium, Uranium and Vanadium from Carnotite." Dr. Wm. M. Grosvenor, chairman of the Section, presided.

Dr. Parsons' lecture was particularly interesting on account of the exhibit and demonstration of various samples of radium, as well as lantern slides and moving pictures. After the lecture there was some discussion in which representatives of the Standard Chemical Co. participated. The discussion was good natured and dealt especially with the applicability of the process to ores of less than 2 per cent U_3O_8 , and the cost and price of radium and the policy of the Bureau of Mines in dispensing with the radium produced in connection with the National Radium Institute (see account below). A leading official of the Memorial Hospital of New York paid a very high tribute to Dr. Parsons' eminent business ability in running the radium factory and gave some information on cancer treatment by radium.

A very full account of the work of the Bureau, done in co-operation with the National Radium Institute, has since appeared in Bulletin 104 of the Bureau of Mines, entitled *Extraction and Recovery of Radium, Uranium and Vanadium from Carnotite*, by Charles L. Parsons, R. B. Moore, S. C. Lind and O. C. Schaefer. (124 pages, with many illustrations.)

As the general method of treatment, used by the bureau, has already been described in our issue of Dec. 15, 1915 (Vol. XIII, p. 965), we give here only some supplementary information on interesting details.

The capacity of the plant is $3\frac{1}{2}$ tons of ore per day, and up to Oct. 10, 1915, nearly 5 grams of radium element had been extracted and approximately $2\frac{1}{2}$ grams of element delivered in the form of radium bromide of such a degree of purity as was desired by the hospitals concerned (the Howard A. Kelly Hospital

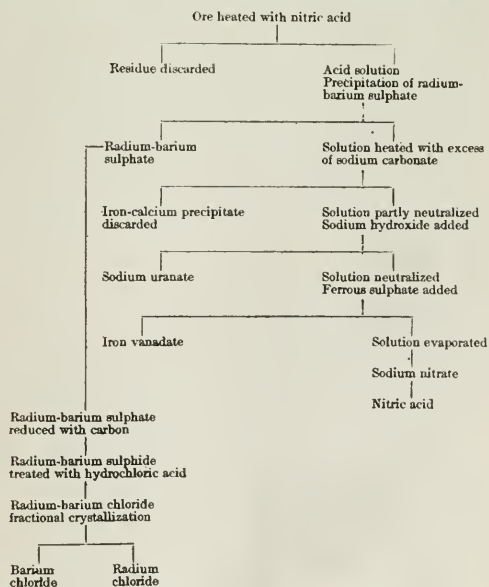


FIG. 1—FLOW SHEET OF RECOVERY OF RADIUM FROM CARNOTITE

in Baltimore and the General Memorial Hospital in New York).

"With ore obtained from Government land or produced at a cost as low as that maintained in the operations of the bureau, it has been shown that the cost of producing radium need not exceed \$40,000 per gram and that the extraction of at least 90 per cent of the radium present may be obtained from good-quality ore, such as the bureau has been able to procure.

"The market price of radium for some two or three years has been \$120,000 and up per gram of element according to purity. At the time of the beginning of the European war there were 16 to 20 grams of radium contracted for abroad, chiefly in Germany, at prices above \$120,000 per gram. Seemingly the war has not affected the market price, but simply the amount produced. As to the selling price of radium in the future, the bureau makes no prediction, but it does not follow that the selling price will decline because of the development of cheaper methods of production. Rather is the case somewhat analogous to the production of gold, diamonds, or any other material that is in steady demand but occurs only in very small quantities. Beyond doubt, the amount of radium in nature is exceedingly small. Other deposits of radium ores may be found, but it is highly improbable that the rarity of uranium ores will ever be greatly modified, so that the price of the finished material will largely depend on the ability to procure the raw material.

"According to the best evidence that the bureau can obtain, and it has investigated the matter carefully, there is not sufficient ore available to maintain for many years even the rate of production of 1914. In this connection it should be remembered that the radium produced by the National Radium Institute is not for sale nor for distribution. The Radium Institute was organized for the purpose of studying the curative properties of radium and not for private gain. The radium produced is being used in two hospitals, the Howard A. Kelly Hospital in Baltimore and the General Memorial Hospital in New York."

According to the agreement between the Bureau of Mines and the National Radium Institute any radium produced in excess of 7 grams of anhydrous radium bromide (RaBr_2) from any 1000 tons of carnotite ore may be donated to the bureau for further experiment and study. This excess output will be supplied to the hospitals of the Army, Navy and Public Health Service.

The ore treated by the Bureau contains 2 per cent or more of U_3O_8 . In considering the work it must be taken into consideration that the problem is to get one part, by weight of radium, out of 200,000,000 parts of ore. This concentration process becomes possibly only by making use of electrical measuring methods by which radioactive elements can be detected and quantitatively measured in quantities far below the limits of any methods based on other properties.

The method of treatment of the bureau (nitric acid leach) is new. Older methods (leaching with sulphuric acid or hydrochloric acid and fusion with sodium sulphate or sodium carbonate) are discussed in the bulletin. If radium is the principal product desired, the nitric acid leaching method is the most direct and efficient. The cost of the nitric acid process is considerably reduced by the fact that sodium nitrate is recovered with small loss and nitric acid once more made from the sodium nitrate, so that the process is cyclic with respect to nitric acid.

In the nitric acid process the radium is at once recovered as a high-grade radium barium sulphate, practically free from silica, and easily treated by improved methods. The process is adapted to recovering

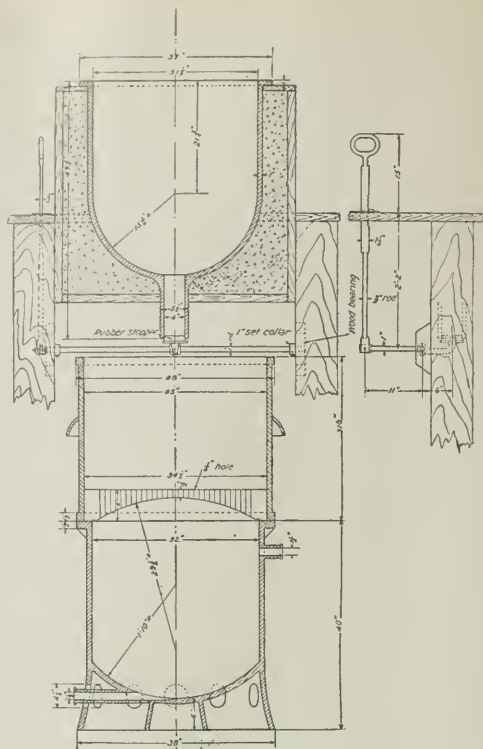


FIG. 2—SECTIONS OF LEACHING POT, FILTER, AND DETAILS OF LEACHING-POT STOPPER

either the radium by itself, or the radium, uranium and vanadium, as the radium is obtained first, and from that point all the other products may be discarded without further treatment, if so desired.

The different steps are each completed in one day, the equipment is not expensive, the extraction and recovery are high, and it is believed that the costs are lower than those with any other process for treating carnotite.

Fig. 1 gives the flow-sheet of the whole process, the different steps of which were already described on page 965 of our issue of Dec. 15, 1915.

Fig. 2 shows sections of the leaching pot, filter, and, at the right, details of the leaching pot stopper. The amount of acid used for leaching is 121 lb. of 100 per cent nitric acid to 500 lb. of ore, the acid being diluted to 38 per cent strength. However, the strength may be varied somewhat, ores high in sulphates requiring stronger acid. The acid is brought near the boiling point by live steam, which has been passed through a baffle in order to eliminate any impurities from the steam. The ore is then run in, being stirred with a wooden paddle during the process. The acid is heated for 15 min. longer, with occasional stirring, and the acid is then run into an earthenware vacuum filter, asbestos filter cloths being used. As much as possible of the sand is held back in the pot by means of a long wooden plug manipulated by hand, and this sand is given an acid wash with acid about one-third of the strength of that used for the first leaching. This sand is then dumped on the filter, and receives two washings with hot distilled water.

Synopsis of Recent Chemical and Metallurgical Literature

Iron and Steel

Electric Furnace Steel in Canada.—In the discussion of a paper by Dr. A. Stansfield, read before the Montreal Metallurgical Association, Mr. J. E. DAVEY, superintendent of the Canadian Brakespur Co., of Sherbrooke, gave the following description of his company's installation.

"We have in operation at Sherbrooke four 5000-lb. basic-lined, three-phase furnaces, and one 2000-lb. furnace. The dimensions of the 5000-lb. furnaces are 70 in. by 108 in. outside lined down to 34 in. x 72 in. wide, while the smaller furnace has a circular hearth of 36 in. in diameter. All the furnaces are mounted on rockers and tilt to pour their charge. We found it very difficult to construct a roof that would withstand the heat of the electric furnace, but finally laid some $\frac{3}{4}$ -in. water-cooled pipes across the furnace and built a roof of silica bricks resting on these pipes. The electrodes are also water jacketed at the point where they enter the furnace, by four coils of $\frac{1}{2}$ -in. pipe. The electrodes are made of 6-in. graphite rods, in 4-ft. lengths, which are threaded and joined together to make one continuous electrode. These are raised and lowered by means of steel wire wound on a drum, passing over a sheave and insulated from the electrode holder, but the electrodes are somewhat unsteady, which causes short-circuiting in the furnace when melting down the scrap. It is intended to install rigid holders so that the electrodes will be raised and lowered in a vertical line. The electrodes for the 1-ton furnace are 4 in. in diameter.

"Each of the larger furnaces is provided with a 500-kw. three-phase transformer which receives the electric current at 6600 volts and delivers it to the furnace either at 40, 70 or 100 volts. The 70-volt connection is usually found the best, as 40 volts would be too low, and with 110 volts the furnace would be difficult to regulate. An ideal arrangement would be to have a transformer to give about 60 volts during the breaking down period, with means for raising this to about 90 volts after the charge has been melted. The transformer is placed as close as possible to the furnace. The cables from the transformer to the top of the furnace are 32 ft. in length; part being flexible to allow of the movement of the electrodes. The cables are composed of fifty No. 6 wires, and the three cables for each furnace are interlaced to reduce inductance losses. The cables are carried overhead, instead of in a conduit, as they are more accessible in case of an accident to the insulation.

"In making a 5000-lb. heat, 2000 to 3000 lb. of scrap, etc., are charged through the doors, which are in the roof, and when this material is melted the remainder of the charge is added to make a total of 5250 lb., thus allowing for the loss of about 4 per cent of the metal. The melting occupies from $4\frac{1}{2}$ to 5 hr., and is followed by refining. A considerable reduction of both carbon and sulphur is effected during the melting, the sulphur being easily reduced to 0.04 per cent or 0.03 per cent, and by means of an oxidizing slag the phosphorus is reduced to 0.02 per cent. The specification limits the carbon to 0.55 per cent, the silicon to 0.30 per cent and the sulphur and phosphorus to 0.05 per cent each, while the manganese must be between 0.40 per cent and 1.0 per cent. The power consumption per ton of molten steel in the ladle is about 600 kw.-hr.; the cost of refractories is about \$2.60, and of electrodes \$2.70 per ton of steel. The molten steel from the furnace is poured into a ladle and the ladle is car-

ried by a 4-ton trolley crane to a turntable, on which are placed enough ingot molds to take the contents of one furnace.

"Although these furnaces, which have been designed and constructed by the Brakeshoe Company, do very satisfactory work, there will be installed by the end of October a 2-ton Snyder single-phase furnace. This is guaranteed to give ten heats of two tons each in 24 hr. and is expected to give twelve heats of 5000 lb. in 24 hr. This furnace has one 5-in. graphite electrode entering the roof, and a steel column passing through the basic lining and the furnace bottom. The electric current is supplied at 220 volts from a substation placed on the other side of a wall. The cables pass through a conduit to the electrode holders. The electric arc varies from 14 to 18 in. in length."

Gold and Silver

Treatment of Antimonial Gold Ore.—According to the *South African Mining Journal* of Oct. 9, 1915, the problem of successfully treating antimonial gold ore on the Murchison Range has been solved by a process introduced by McArthur Forrest & Company. In brief the process consists in dissolving the antimony sulphide from the crushed ore with a hot solution of caustic soda, recovering this constituent as a saleable product and cyaniding the residue for gold. At the United Jack property the process is as follows: The ore is crushed in ball-mills to 30-mesh and delivered to vats 23 ft. in diameter and 8 ft. deep. Caustic soda solution is then pumped on the pulp and leaching is conducted as in cyanidation. The resulting solution is treated with carbonic acid gas from a lime kiln, which precipitates the antimony sulphide in an amorphous condition. The mixture is filter-pressed and the resulting cake marketed. The solution is returned for further use. The sand residue, containing gold is then cyanided in the usual manner. The original ore is reported to contain gold to the value of \$7 to \$8 per ton and about 12 $\frac{1}{2}$ per cent antimony sulphide.

Copper

Pyrite Smelting at Mount Lyell.—In his address as president of the Australasian Institute of Mining Engineers, Mr. ROBERT STICHT has given the most interesting and instructive account yet published of the smelting practice at Mount Lyell. The address appears in full in the Society's *Proceedings*, No. 19. Introducing his remarks by saying that pyritic smelting is something "in which doing is decidedly more difficult than speculating on the 'underlying principles,'" the author proceeds to outline "how it is done" rather than "why it works." We give herewith his "mental picture" of the process, leaving some other details for further presentation.

"In order to understand our method, it is necessary to form a correct mental picture of the inner appearance and working condition of the pyrite furnace. Its most salient feature is a pronounced openness or porosity of the masses in action, together with a total lack of stratification or bedding, yet with an even distribution of the various components of the charge throughout each horizon. There is no layer-like arrangement of the different materials, and no alternation of charge and fuel. There is no reducing zone, but an oxidizing one, restricted, like the first-mentioned, to the lower regions of the column. In distinction from the ordinary furnace, in which a distinct reducing zone precedes the slag-forming zone, the oxidizing and the slag-forming zone are identical. From top to bottom, however, there is one element of the charge present everywhere, which forms the skeleton, so to say, of the

furnace-body in action. This element is the *free silica* in charge. The lumps of quartzite, etc., are present in excess of the quantity required for the momentary furnace action, and they build up a honeycombed or vesicular column, reaching from the crucible of the furnace upward to the stock-line, or top of column. This silica skeleton is a necessity. Without it pyrite smelting is unthinkable. It forms a physical structure like an aggregate of cells, each cell in the heart of the furnace forming a little Bessemer vessel with silicious walls. The wasting away of the material of the walls with scorification does not unsettle the fixity of the column, for the lumps of silica are constantly being replenished by new ones settling down from above.

More particularly, the furnace column may be divided into three regions—an upper preparatory one; a central one, where the entire chemical activity takes place; and a lower one, extending from above the tuyeres to the bottom of crucible, in which no action takes place. The first contains the charge undergoing only primary chemical and physical changes, the second is the seat of oxidation and scorification, and the last only forms a passageway and receptacle for the molten products. The most important region is the central one. It is situated some distance above the tuyeres, much higher up in the shaft than the slag-forming zone of the ordinary furnace, and fluctuates up and down in position in accordance with the variations in the pneumatic conditions within the shaft, its location being principally decided by the volume of blast blown in. To characterize it as that part of the shaft or column in which the vital functions of the pyrite furnace are in play, I have designated it the 'focus.' The three zones doubtless merge into each other, the lower preparatory zone and the upper reaches of the focus probably not being clearly defined. The lower margin of the focus, however, is probably sharply divided from the basal region. The furnace activity is all upwards, not downwards, the sinking of the fused products and the silica excepted.

The preparatory zone is probably not so high as in the ordinary furnace, and has the usual functions of driving out moisture and preheating the masses by means of the escaping gases. It has also a very special one, in the case of the pyrites, without which the further furnace action would not take place as it does. This consists in the sublimation of the volatile sulphur atom out of the pyrites, at the top of the zone, and the fusion and superheating, lower down, of the residuum, the composition of which, through the loss of about three-sevenths of the total sulphur, is practically that of pyrrhotite, FeS_2 .

In this uppermost zone no chemical action affecting the ores on charge takes place, and heat is only being absorbed, but it appears that within this zone a chemical interchange is enacted, accompanied by the evolution of a small amount of heat, between the heated sulphur dioxide, coming up from below, and the coke fed in, as soon as the latter sinks to a horizon where it is hot enough. If the amount of coke is small, it probably does not survive this reaction, and no coke gets down to the focus. Should the amount of coke be large, then some may reach the focus, but it will necessarily interfere with the reactions there, and spoil the pyritic work. A small amount of coke on charge is, however, still a *sine qua non*, and seems required to support the work going on in the preparatory zone, even though its thermal effect is low, under the circumstances. As soon as the melting point of the pyrrhotite residuum is reached in this zone this substance melts, and we now have the phenomenon of an incandescent, honeycombed mass of silicious material in lumps, in the in-

terstices of which aggregate the molten sulphide courses downward, towards the focus, in a heavy shower.

The atmosphere in the preparatory region consists only of the neutral gases forming the products of combustion from the focus, and the CO , out of the limestone and coke, and is heavily charged with sulphur vapor, derived from the disintegrating sulphide of iron and the reaction between coke and sulphur dioxide. By far the chief constituent is nitrogen; then follow sulphur dioxide and carbon dioxide. There is, or should be, an absence of oxygen, and consequently no roasting or other oxidizing action can take place in this zone. In the lower portion of the preparatory zone the limestone may be calcined, but this is more likely to be completed in the upper regions of the focus.

Physically, the preparatory zone represents a mere jumble of charge constituents undergoing certain changes. Yet the distribution of the constituents should be homogeneous and properly balanced, otherwise the furnace will not work well. Occasionally it may be necessary temporarily to disturb this regularity of mixture by placing more pyrites, or more silica, or more slag, here or there, for the purpose of curing irregularities in the descent of the masses, to relieve the beginning formation of accretions, or to close blow-holes, etc., but even this treatment, though of a curative nature, cannot be persisted in too long."

Recent Chemical and Metallurgical Patents

Detinning

Electrolytic Detinning.—In the alkaline electrolytic detinning process it has heretofore not been possible to construct an apparatus made up of a plurality of cells connected together owing to the difficulty of circulating the electrolyte and of preventing the supply pipes from becoming plated with tin, thereby reducing their inside diameter. The process has, therefore, been carried out in single cells. According to a patent of Dr. HANS GOLDSCHMIDT of Essen, Germany (assigned to Goldschmidt Detinning Company of New York), it is now possible to carry out this process in a large number of cells, connected in series with each other, to maintain a good circulation of electrolyte, and also to prevent the circulating pipes from becoming plated with tin. This is accomplished, as shown in Figs. 1 and 2, by providing a reservoir tank 1 above the electrolytic vats and connecting this tank with the vats by a series of pipes as shown. The pipes are made of decreasing diameter as they approach the vats, as this has been found to be very important in providing a good flow. The ends 27 of the pipes, which supply the fresh solution from the high tank, do not touch the liquid and are made of rubber, thus preventing any possibility of becoming obstructed due to tin coating. Each cell has its own

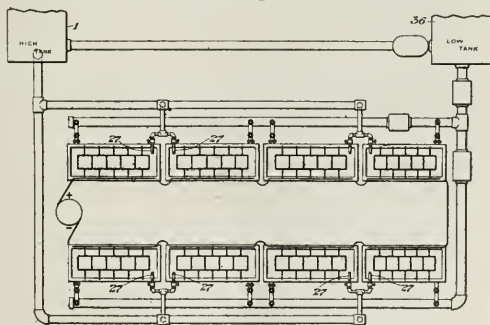


FIG. 1—ELECTROLYTIC DETINNING SYSTEM

inlet and outlet pipe directly connected to the large tanks. The lower tank 36 receives the outlet, and it is pumped from here to the upper tank.

A temperature of 70 to 80 deg. C. is maintained, and a high current density, 800 to 1000 amp. per square foot,

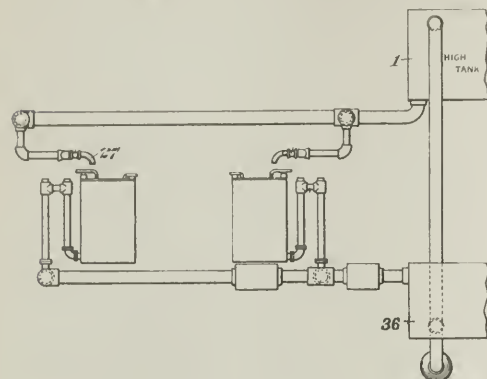


FIG. 2—ELECTROLYTIC DETINNING SYSTEM

is used. The electrolytic vats are made of cast iron encased in wood and form the cathodes. The anodes are usually in the form of a basket containing the material to be detinned. The solution used for the electrolyte is a mixture of stannate of soda and caustic soda with an excess of caustic soda. Carbonic acid from the air is taken up, forming sodium carbonate. The process is continuous as the electrolyte is regenerated, as it is circulated through the system (1,160,400 and 1,160,401, Nov. 16, 1915).

Detinning Process.—A rather novel process for removing metallic coverings from other metals, such as tin from tinned steel scrap, is patented by Dr. HANS FOERSTERLING and HERBERT PHILIPP of Perth Amboy, N. J. (assigned to Roessler & Hasslacher Chemical Company). This process depends on the alloying properties of alkali metals with other metals, such as tin, and as

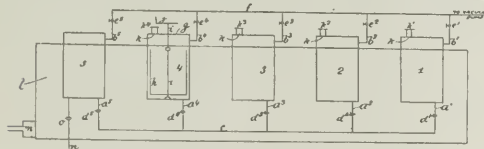


FIG. 3—SODIUM PROCESS OF DETINNING

applied to detinning it consists in treating the tin scrap in a heated container with molten sodium. In Fig. 3, numbers 1, 2, 3, 4 and 5 represent iron vessels provided with drain pipes a_1, a_2, a_3, a_4, a_5 and vacuum pipes b_1, b_2, b_3, b_4, b_5 . A common pipe C connects all the drain pipes and a common vacuum pipe f leading to a vacuum pump connects the separate vacuum pipes. Stop cocks are provided on all pipes. In conducting the process all the vessels are placed in one furnace as a unit and heated by the gas burner m . Vessels 1, 2, 3 and 4 have openings k in the top, and vessel 4 has a removable cover and a revolving basket h inside, rotated by shaft i and wheel j . When the process is running, vessel 3 will contain a 25 per cent tin-sodium alloy, vessel 2 a 5 per cent tin-sodium alloy, and vessel 1 pure sodium. The temperature is maintained at about 400 deg. C. The basket h is filled with tin scrap and the cover put on. The vessel is then evacuated, the vacuum shut off and the alloy from vessel 3 allowed to run in. The basket is

then rotated, when the tin from the scrap alloys with the sodium very quickly. A vacuum is then created in 3 and the alloy run back again. In like manner the tin scrap is treated with the weaker tin-sodium alloy from 2, and then with the pure sodium from 1, after which the scrap is removed and fresh scrap put in. After the alloy in 3 has reached 50 per cent it is conveyed into vessel 5, when it may be led away through pipe n for distilling off the sodium and recovering the tin. The alloy from 2 is run into 3, the alloy from 1 is run into 2, and fresh sodium placed in 1. Thus a continuous process is formed. The rapidity of action of the sodium is noteworthy. The following table shows the time required:

Alloy	Per Cent Tin in Scrap Start	Per Cent Tin in Scrap Finish	Time, Min.
60 tin 40 sodium.....	1.8	0.44	10
50 tin 50 sodium.....	1.8	0.22	10
40 tin 60 sodium.....	1.8	0.13	10
30 tin 70 sodium.....	1.8	0.015	10

"The residual iron when removed from vessel 4 still contains traces of sodium, and when molten shows a superior quality over ordinary iron" (1,160,590, Nov. 16, 1915).

Electrolytic Furnaces

Manufacture of Amides, Cyanamides and Cyanides.

—A continuous process for the electrolytic production of amides, cyanamides and cyanides is patented by Edgar A. Ashcroft of London, England. This process is based on his previous patent (801,199, Oct. 10, 1905). The reactions taken advantage of are those of ammonia and metallic sodium forming sodium amide between 120 and

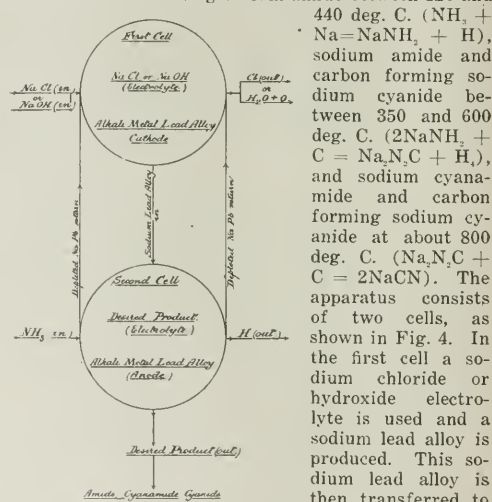


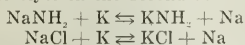
FIG. 4—DIAGRAM OF PROCESS

the anode for the production of amide, cyanamide or cyanide. The electrolyte used in the second cell is made up of the product which it is desired to obtain. For instance, for producing sodium amide, an electrolyte of sodium amide is used, and as ammonia gas is conducted in more sodium amide is formed, which continuously augments the electrolyte. The sodium amide is tapped from time to time as produced. It is possible in making sodium amide to use a solution of the raw materials in the first cell and a mercury cathode, but in making sodium cyanamide a mercury cathode is not suitable. In making cyanamide the procedure is the same as in making amides except that carbon is added to the electrolyte in the second cell to react with the amides as

fast as formed and the higher temperature is needed. In making cyanide the temperature is raised further to about 800 deg. and an electrolyte of cyanide is used. The depleted alloy is returned to the first cell for reuse. It is claimed that the process is more economical and efficient than previous processes (1,163,498, Dec. 7, 1915).

Manufacture of Sodium Alloys.—In electrolyzing fused caustic alkalis for producing alkali metals using insoluble anodes, it has generally only been possible to obtain half the current efficiency owing to one molecule of the alkali out of every two formed being required to decompose the water formed by the reaction, $2\text{NaOH} = 2\text{Na} + \text{H}_2\text{O} + \text{O}$. In order to increase this efficiency, EDGAR A. ASHCROFT of London, England, proposes to use a higher temperature and provide for the escape of oxygen and steam, instead of oxygen and hydrogen. Further features of the process are the maintaining of only a thin layer of the alkali hydroxide above the heavy metal alloy cathode, and the agitation of the electrolyte and alloy cathode by a pump and magnetic stirring device and the use of a higher current density at the anode. The process is carried out in a copper-lined or nickel-lined cell, either singly or in conjunction with a secondary cell, for the production of amides, cyanamides, or cyanides. An annular plate of nickel is used as anode. The temperature used is between 400 and 500 deg. C., as compared with 330 deg. in previous processes, and efficiencies of from 60 to 80 per cent are claimed. The process is suitable for employment in large units and currents up to 10,000 amp. may be used in a double cell (1,161,585, Nov. 23, 1915).

Apparatus for the Manufacture of Sodium and Sodium Alloys.—In processes for making sodium by electrolysis of a fused mixture of sodium and potassium chlorides with a molten lead cathode, it has heretofore been difficult to produce sodium free from potassium, due to potassium alloying with the sodium and lead in the primary cell and passing into the final product. In an apparatus patented by EDGAR A. ASHCROFT of London, England, these difficulties are claimed to have been overcome. Reversible reactions, such as the following, have been found to occur between the electrolyte and alloy in the primary cell and between produced alkali metal and electrolyte in the second cell:



It has been found that these reactions may be controlled in such a way as to produce sodium which is practically free from potassium. The second reaction takes place more readily from left to right, and this fact may be made use of by electrolyzing a mixture of 40 per cent sodium chloride and 60 per cent potassium chloride and forming the lead-sodium-potassium alloy as usual. This alloy is then separately heated with a fresh electrolyte of NaCl, which removes the K from the alloy. The chlorides are then conducted to the first cell and the alloy free from K to the second cell for further use. This "triple" procedure has been found unnecessary, however, in most practical cases, and the following procedure has given a good product: The electrolyte in the first cell, consisting of sodium chloride with 2½ per cent or less of potassium chloride, is kept in whirling motion by creating a magnetic field around the cell by a metallic conductor. The anode is a hollow graphite cylinder placed at the center so made as to carry off the chlorine generated which is forced toward the center by the whirling motion. The first or primary cell is lined with a basic insulating lining as a temperature of about 750 deg. C. must be maintained (molecular proportions of sodium and potassium chlorides melt at 670 deg. C.). The whole apparatus is cast in one piece of

steel, and another feature is the addition of an intermediate receptacle for the alloy connected by weirs and overflows to both cells so that changes in bulk will not affect the continuous operation of the cells. The alloy flows continuously from the first cell into the intermediate receptacle, and is pumped or flows from there into the second cell as required, a constant level being always maintained. Passages are also provided for conducting the depleted alloy back to the first cell (1,159,154, Nov. 2, 1915).

Manufacture of Cyanides and Cyanamides.—An electrolytic process for manufacturing cyanides and cyanamides is patented by CHARLES E. ACKER of Ossining, N. Y. (assigned to Nitrogen Company of New York). In an electrolytic furnace 1 (Fig. 5) of cast

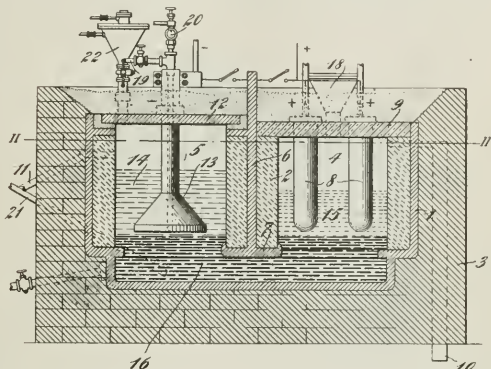


FIG. 5—ELECTROLYTIC FURNACE FOR CYANIDE PRODUCTION

iron or steel there are a primary chamber 4 and a secondary chamber 5, partially separated from each other by the wall 2 of refractory material. The anodes 8 are of carbon and the cathode 13 is of iron, nickel or carbon. The electrodes are adjustable. The chambers 4 and 5 are closed at the top by covers 9 and 12. The primary electrolyte consists of molten barium chloride with a small amount of sodium chloride at the beginning of the operation. The secondary electrolyte consists of molten sodium cyanide. Both electrolytes rest on a bath of molten lead shown at 16. In starting the process the electrodes are raised slightly above the surface of the lead before turning on the current. Barium and sodium are liberated in the primary cell, an alloy of lead, barium and sodium being formed. This alloy is put into circulation by means of a centrifugal pump and soon becomes homogeneous and of uniform temperature. In the secondary chamber, in which the lead-barium sodium alloy is the anode, the barium combines with CN ions set free by electrolysis, forming barium cyanide. Metallic sodium is liberated at the cathode, which reacts with the barium cyanide, forming sodium cyanide and barium. Charcoal is introduced through hopper 22, having first been exhausted of its air by a pump. The barium set free by the metallic sodium combines with the carbon forming barium carbide, which remains suspended in the cyanide. Either ammonia or atmospheric nitrogen is then introduced through pipe 19, passing down through cathode 13, or through pipe 21, directly to the molten metal. The latter pipe is used when it is desired to preheat the nitrogen-containing gas by means of the molten metal, as in the case of air. The nitrogen then combines with the barium carbide forming barium cyanide, and thus a cyclic process is formed. As soon as sufficient barium has been added to the process through the primary cell it is unnecessary to add more, and the primary electro-

lyte may consist only of sodium chloride. When enough cyanide has been formed the charge is clarified by stopping the flow of gas first, then the liberation of sodium, and allowing the mass to settle. Barium carbide with the excess carbon will settle and the cyanide may be tapped off, or the sodium supply may be cut off and the product drawn off as a mixture of barium and sodium cyanides (1,160,811, Nov. 16, 1915).

Blower for Flotation and Smelter Work

A blower which meets successfully the requirements of flotation and smelter service in which the air supply is so essential a consideration, is shown in the accompanying illustrations. This blower is known as the Boston type blower and is made in various sizes, according to capacity and pressure desired, by the Connersville

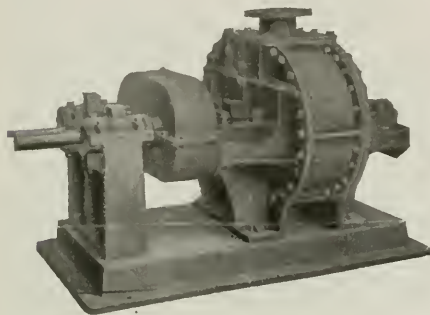


FIG. 1—BOSTON TYPE BLOWER

Blower Company, Connersville, Ind. It is rationally designed for high-pressure work and has found much application in smelter and flotation work. Fig. 1 shows the blower complete and Fig. 2 shows the interior construction and principle of its operation. The rotating parts, called impellers, do not come in contact with each other or with the case at any point in the revolution. They are finished all over with at least two cuts and are separated by accurate clearances so that there is no internal contact or wear and no need for internal lubrication. The impellers are symmetrical, carefully balanced and heavily ribbed internally. They are pressed and keyed onto the shafts and may be operated at high speeds without vibration.

The losses of a positive pressure blower are confined to mechanical friction and slippage. The slippage loss is determined by the pressure, regardless of the speed.

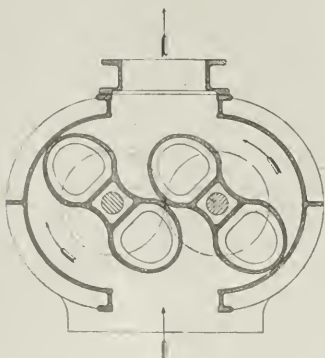


FIG. 2—INTERIOR OF BLOWER

Therefore, high speed is desirable because it means high efficiency by reason of the low per cent of slippage loss. Blowers not so well made cannot safely be operated at economical speeds.

One element contributing to the serviceability and efficiency of this high pressure blower is the type of gear which is used exclusively. This is the epicycloidal radial flank gear whose tooth curve is generated by a rolling circle the diameter of which is one-half the pitch diameter of the gear. The tooth has minimum curvature and maximum working surface. Its action approaches rolling contact.

Special cutters are used, each designed for only one pitch diameter and one number of teeth. This practice and the fact that the tooth is thickest at the pitch line and can be accurately calipered at both ends, gives a two and three-point working contact as against the one-point contact of ordinary gears. The latter necessarily transmit their power in a series of small impulses or blows at once noisy and destructive. The gears operate in a bath of oil fully protected from dust or injury, being contained in a cast iron housing apart from the blower case. They are supported by bearings on both sides. This construction eliminates vibration, insures correct meshing and a contact the full width of the gear face.

The Latest Improvements in Brinell Hardness Testing Machines

The Scientific Materials Company of Pittsburgh has made extensive studies and numerous practical tests with all existing types of Brinell metal hardness testing machines and has succeeded in developing a much improved model.

The most important drawback in the design of old styles of such apparatus (most of which work on the hydraulic principle) is that the transmission and measurement of pressure is not constant, thus introducing serious errors in the determinations, which increase with the age of the machine. Ground cylinders for pressure transmission can never produce that constancy which is essential in a first-class testing machine.



FIG. 1—SCIMATCO-BRINELL HARDNESS TESTING MACHINE, 3000-KG. CAPACITY, DIRECT-READING FOR DEPTH OF BRINELL INDENTATIONS

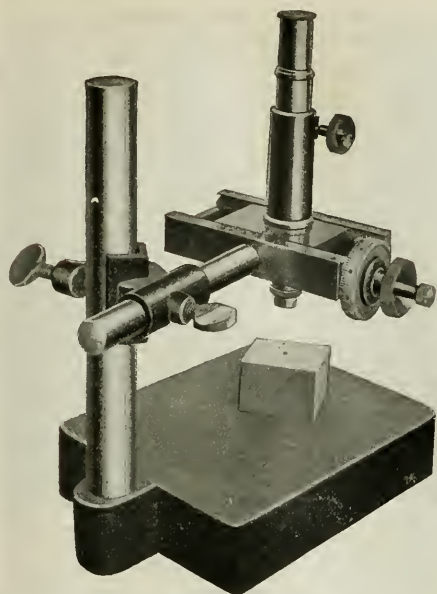


FIG. 2—SCIMATCO-BRINELL MICROSCOPE FOR DIAMETER MEASUREMENTS, DIRECT READING

Another important point established in a long series of tests run in the metallographic laboratory of the Scientific Materials Company and confirmed by separate research work along the same lines at the U. S. Bureau of Standards is that the method of determining the hardness of metals by measuring the depth of indentation of the Brinell ball is far more accurate than the method of estimating the hardness from the diameter of such indentations. Furthermore, the depth measurement permits the detection of small differences in hardness and allows the direct reading of the correct result, eliminating all tedious calculations.

The Scientific Materials Company has succeeded in embodying a direct-reading depth gauge in the design of its new Brinell machine and has eliminated the serious errors of old types, by using the only correct

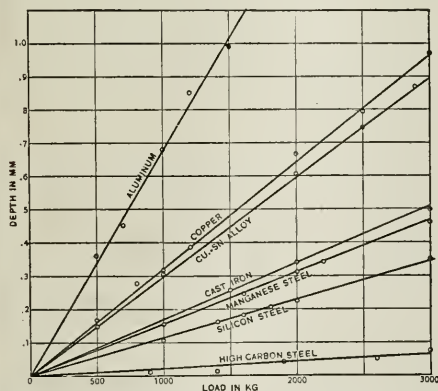


FIG. 3—RELATION BETWEEN PRESSURE AND DEPTH OF INDENTATION ON METALS OF DIFFERENT HARDNESS

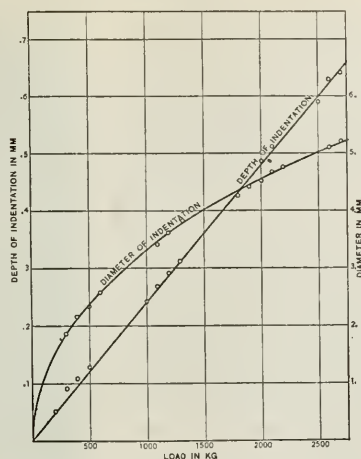


FIG. 4—RELATION BETWEEN DIAMETER AND DEPTH OF INDENTATIONS ON ONE BAR OF BESSEMER STEEL, AT VARIOUS PRESSURES

method of hydraulic pressure transmission. As will be understood from Fig. 1, the hydraulic pressure is produced in the bottom vessel of the machine by the turning of a spindle. This permits a steady and finely regulated increase and decrease of the pressure and represents a considerable improvement over the old pumping devices which naturally raise the pressure in jerks.

The hydraulic pressure is then transmitted by a metallic vessel filled with liquid which acts similarly to the closed diaphragm vessel of an aneroid barometer. This is the most accurate and only constant method of hydraulic pressure transmission known to modern science. By this "hydraulic dynamometer" all variations in friction are automatically eliminated. Since there is no friction in the Scimatco machine, there can be no friction variations, and thus the most serious error of the old types of similar machines can never occur in this improved hydraulic press. A very simple and effective controlling device is provided to check and regulate the volume of liquid in the dynamometer vessel, so that this feature is also at all times under full control.

The direct-reading depth gauge carried by the Scimatco-Brinell machine is designed and constructed in such a manner that it will give correct indications to 1/100 of a millimeter, independent of the shape of the test piece. The stage, on which the specimen rests, is automatically levelling so that pieces of irregular shape can be readily investigated. The pressure gauge embodied in the Scimatco machine consists of two separately acting, but self-contained, pressure-measuring units: one is used as "working gauge" in the routine determinations and the other acts as "standard" to check the working gauge from time to time, say, once every month. The connection between these two gauge units and the pressure vessel can be conveniently made and interrupted by spindle valves.

The dial of the gauge is uniformly graduated in equal units, and not in kilograms. A calibration certificate is furnished with each machine, showing the pressure equivalents of these units. The uniformly and finely divided gauge is much easier to read than ordinary pressure gauges which must naturally be unevenly divided, and, in case the calibration of the "working

gauge" should show deviations after a certain time, it will only be necessary to change the calibration certificate.

Should it be necessary to measure the diameter of the indentations, for the purpose of comparing results with those of other investigators who have no means for ascertaining the depth of Brinell indentations, it can be done after the specimen is removed from the machine. For the purpose of very accurate diameter measurement, the Scientific Materials Company has constructed a special measuring microscope (Fig. 2) mounted by universal clamp on a very substantial support and base, permitting convenient diameter measurements on heavy and irregular shaped metal pieces by direct-reading scale.

The eye-piece of this precision instrument carries cross hairs which are focused against the indentation. Then the joint of the cross hairs is set against one side of the indentation, the position of the scale and graduated micrometer screw noted, then moved to the other side of the indentation and the position again carefully noted. The difference between the two positions gives the diameter of the indentation with an accuracy of 1/1000 millimeter.

Figs. 3 and 4, taken from a recent publication of the U. S. Bureau of Standards, will illustrate the superiority of the method of determining hardness by measuring the depth of indentations instead of diameters. Fig. 3 shows plainly that in testing the hardness of soft, medium, and hard metals the depth of indentation at various pressures forms a straight line, thus proving beyond doubt the consistency and accuracy of results.

Fig. 4 shows that on one and the same piece of metal the diameters at different loads are not in proportion, while the depth measurements show a straight line.

Magnetic Clutch-Brake in Rubber Mill

BY C. B. FERGUSON

In the plant of the Boston Woven Hose & Rubber Company it was planned to drive the rubber mills in groups from a single shaft by means of a synchronous motor of 650 hp. The use of a synchronous type motor was desirable because of its characteristic of raising the power factor of the power system. Two problems were presented—one the safety stop feature of every rubber mill, the other the starting of the synchronous motor.

The safety stop feature is an important one in the rubber mill room of to-day. The easy means of throwing off the driving power and applying a powerful brake has saved many hands, arms, and even lives. This feature is provided by the Cutler-Hammer magnetic clutch-brake installed and shown in the illustration Fig. 1.

The starting of the synchronous motor is another problem. With this type of motor means of easy and gradual acceleration of a considerable load must be provided to prevent the load from being thrown on the motor too suddenly and pulling the motor out of step. Since the station supplying power for this synchronous motor was already loaded up to its capacity it was important to provide means of properly accelerating the

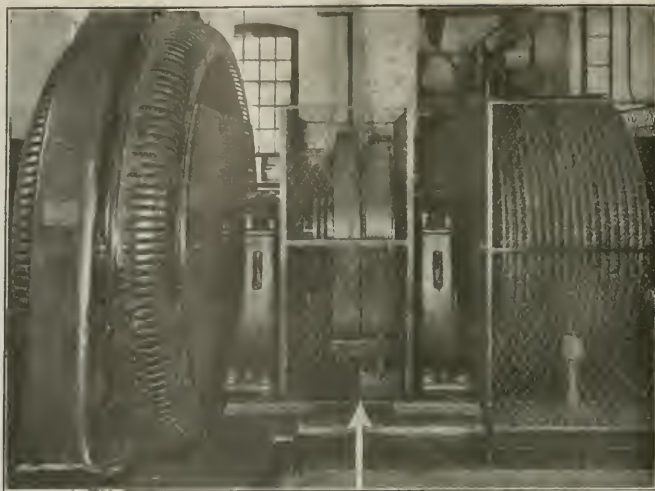


FIG. 1—MAGNETIC CLUTCH-BRAKE USED ON MILL DRIVE IN PLANT OF BOSTON WOVEN HOSE & RUBBER CO.

Motor is of synchronous type—650 hp. Arrow points to clutch-brake

motor. This means consisted of the magnetic clutch-brake referred to above.

The equipment consists of a synchronous motor mounted on a common sub-base with a rope sheave, the magnetic clutch-brake furnishing the connection between the motor and the rope sheave. The motor is rated at 650 hp., runs at 240 r.p.m., and under normal conditions carries practically full load when the mill line is operating. Safety switches are installed in the mill room and a slack cable switch in the motor room to stop the motor and line shaft in case of the driving rope breaking.

The chief points of this installation are, therefore, safety in the mill room is provided by safety switches which stop the mills in case of accident; gradual acceleration of the synchronous motor is obtained by means of automatic rheostat and clutch-brake; accidents are prevented because the motor cannot be started by closing one of the safety switches, the station operator must do it by closing the panel switch; the slack cable switch in the motor room automatically disengages the clutch and causes the brake to be applied in case the driving ropes break; a stopping push button is provided on the control panel for ordinary stops when the clutch is simply released but the brakes not applied, thus saving unnecessary wear.

With reference to details of the clutch-brake or clutch-brake accelerator, as sometimes called, it should be noted that the clutch portion consists of a solid circular steel casting, mounted on the driving or motor end of the shaft. This member of the clutch carries embedded in its periphery a single cylindrical magnetizing coil, the terminals of which are brought out to an ordinary pair of slip rings. Mounted concentrically with the coil and the outer periphery, is supplied an adjustable ring of friction so that the metal faces of the driving and driven member do not come directly in contact with each other. This also serves the purpose of providing a permanent air-gap in the magnetic circuit. The other member of the clutch, keyed to the driven or rope pulley side of the shaft consists of a circular steel armature secured to the hub by means of a flat circular spring plate, so that when the magnetizing coil is energized, this circular armature is drawn toward the driving

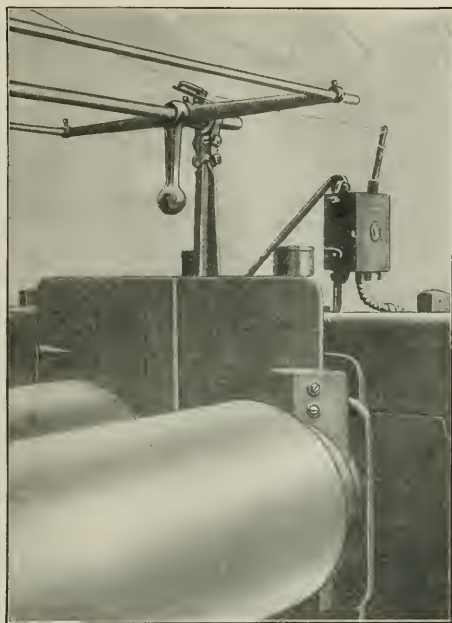


FIG. 2—SAFETY SWITCH

It is tripped when rod on either side of rolls (running parallel with them) is pulled down. This throws out the clutch and causes brake to be applied instantly.

member of the clutch, the motion along the shaft being accomplished by a slight dishing of the spring plate upon which it is mounted.

It will be noted from the description just given of the clutch portion of this equipment, that this particular form of clutch possesses the advantage of instant disconnection in case of interruption of the magnetizing current and does not require a portion of a revolution for its disengagement. Another feature easily understood from the above description is that with this form of clutch, there is no tendency for it to either release itself or to lock itself due to the mechanical forces exerted as it comes up to speed and while it is running at full speed.

Secured to the hub of the driven member is an ordinary brake pulley, over which there is carried a band brake of the locking type, automatically released by a solenoid mounted on a separate stand in proper relation to the brake beam. The clutch itself is 54 in. in diameter.

Throughout the mill room safety switches (Fig. 2) are installed and these are arranged in series electrically so that the clutch will be disengaged and the brake simultaneously applied, if a safety bar, one of which is provided for each mill, is tripped. In the motor room there is provided a single push button for engaging the clutch, and the clutch is energized by means of an automatic rheostat in such a way as to make it pick up the load gradually and at the same rate of speed for each start.

One novel feature of the electric control system is that if the clutch is disengaged by the operation of any one of the safety stations located throughout the mill, as stated above, the brake is simultaneously applied. If, however, the clutch is disengaged by means of a stopping button on the motor-control panel, the brake is not applied but the load is allowed to coast to rest. Con-

sequently, the quick stop is obtained only in case of an accident.

Another feature of the control system is that when the safety stations have once been tripped, they can be reset immediately, but power cannot be put back on the mill line until the single starting button located on the motor-control panel has been operated. A slack cable switch is also provided so that in case of breakage of the rope drive the clutch is automatically disengaged and the brake applied.

Obituary

James Mapes Dodge, chairman of the Board of the Link-Belt Company and a pioneer in the development of conveying and elevating machinery, died at his home in Philadelphia on Dec. 4, 1915. He was born June 30, 1852, at Waverly, N. J., and received his education at Rutgers College and Cornell University. After a varied experience in the East, partly with shipbuilders, he went to Chicago, where he joined with William D. Ewart,



THE LATE JAMES M. DODGE

inventor of the Ewart link-belt, in the development of the chain business. At that time, about thirty-five years ago, the application of chains to power transmission was exceedingly limited, and their use in elevating and conveying machinery was practically unknown. Later Mr. Dodge came to Philadelphia and formed a partnership with Mr. E. H. Burr, to handle the Ewart chain. Out of this partnership the Link-Belt Engineering Company grew in 1888. In 1889 he developed the conical pile system of storing coal, for which he received the Elliott Cresson gold medal in 1907 from the Franklin Institute. He designed the links and attachments for all of the link-belts now used by the Link-Belt Company.

Fertility of invention and mechanical ingenuity combined with a high order of executive ability were the qualities which brought Mr. Dodge his success. He was for many years closely associated with the late Frederick W. Taylor, in the accomplishment of remarkable results for the benefit of both employers and employees, in a wide circle of industries. His influence was always towards the development of self-help, initiative, ambition, and responsibility in the men, and of a spirit of fair play and humanitarianism as real business assets. Mr. Dodge was a past president of the American Society of Mechanical Engineers, a vice-president of the Franklin Institute, and a member of various other clubs and societies.

Personal

Mr. H. W. Hardinge has been awarded the John Scott medal by the Franklin Institute of Philadelphia for the invention of his conical mill.

Mr. S. A. Ionides of Denver is on a professional trip which will take him through California and the Northwest.

Mr. R. J. Johnston has been appointed superintendent of the Donora zinc smelter of the American Steel & Wire Company.

Mr. W. J. Lakeland of the Burma Mines, Ltd., has arrived in this country from Burma for a visit to the mining and metallurgical centers of the West.

Mr. F. W. McNair, president of the Michigan College of Mines, has been on a trip through the Western States, traveling to the Pacific Coast.

Mr. Benjamin Magnus, formerly general manager for the Mount Morgan Gold Mining Company, Ltd., of Mount Morgan, Queensland, has opened an office as consulting engineer at 61 Broadway, New York City.

Mr. Ernest B. Pearce will have charge of the new tin smelting plant of the American Smelting & Refining Company at Perth Amboy, N. J. Mr. Pearce has had considerable experience in tin smelting in other countries.

Mr. F. Peiter has severed his connection as coke oven engineer with the Gas Machinery Company, Cleveland, Ohio. Mr. Peiter was formerly connected with H. Koppers Company, as designing and constructing engineer, and also with the Tennessee Coal & Iron Company.

Mr. W. R. Rust has resigned the presidency of the company operating the Tacoma smelting plant, which is controlled by the A. S. & R. Co., and will retire from the management of the property.

Mr. W. L. Saunders, president of the Ingersoll-Rand Company and member of the Naval Consulting Board, gave a talk on "Preparedness" at the annual banquet of the Plainfield, N. J., Board of Trade on Dec. 2.

Mr. E. A. Cappelen Smith has been elected a director of the Chile Copper and Chile Exploration companies. Mr. Smith is at present in Chile.

Mr. W. E. Tracy, who for some years past has been superintendent of the mill of the Liberty Bell Company at Telluride, Col., has severed his connection with the company and has gone to Plainfield, N. J.

Book Reviews

Electrothermic Smelting of Iron Ores in Sweden. By A. Stansfield. Bulletin 344, Mines Branch, Department of Mines, Canada. Ottawa: Government Printing Bureau.

This monograph of 67 pages is a most timely publication. It narrates the observations of Professor Stansfield of McGill University (well-known for his valuable book on *The Electric Furnace*), while on a vacation trip in Norway and Sweden in 1914. The data given were accumulated and are discussed with particular reference to Canadian conditions and possibilities.

Interesting points brought out are: The Swedish electric furnaces make charcoal pig iron cheaper than Swedish charcoal blast-furnaces; the thermal efficiency of utilization of the electric energy is 68 to 74 per cent; the system of gas circulation is cumbersome but does not increase the output per kw. year; the cost of making charcoal pig iron in Canada, with power at \$10 per hp. year would be \$20 to \$21 per ton, of coke

iron, \$18.50 to \$19.50. At present, the author sees prospects in Canada only for the electric production of high-grade charcoal pig iron.

* * *

The Sampling and Chemical Analysis of Iron and Steel. By O. Bauer and E. Deiss. Translated by W. T. Hall and R. S. Williams. Octavo, 373 pages, 135 illustrations. Price, \$3.00 net. New York: McGraw-Hill Book Co., Inc.

The translators have rendered a distinct service to their chemical colleagues in translating this fine work. Professor Bauer wrote the 125 pages on sampling, and Mr. Williams translated it; it should be read by every man entrusted with taking samples of iron or steel for analysis. Mr. Deiss wrote the rest of the book, on methods of chemical analysis, including in it only the methods found reliable at the German Royal Testing Bureau, Gross-Lichterfelde, Berlin, and omitting rapid "works methods." The translators have amplified this part by adding about 25 quick methods, mostly of American origin, including also, Walker and Patrick's test for total oxygen. It is a keenly practical book, for the use of expert analysts anxious to get results of high reliability and accuracy.

* * *

The Rare Earth Industry. By Sydney J. Johnstone. Octavo, xii + 136 pages; 42 illustrations. Price \$3.00 (7s. 6d. net). New York: D. Appleton Co.

The principal chapters of the book are on thorium and cerium, titanium, zirconium, tantalum and niobium, tungsten, uranium and vanadium. The contents also include the manufacture of incandescent mantles, pyrophoric alloys and electric incandescent lamps; a final chapter of 18 pages, on "The Industry of Radioactive Substances," was written by A. S. Russell.

The treatment is principally technical and commercial with special emphasis on statistics of production and cost. Each chapter gives, regarding the rare element, a fairly complete bibliography, its occurrence, production, treatment, uses and methods of analysis. The field covered is so extensive and varied that the author could not have first-hand information on every topic, as a necessary consequence some of the statements (e.g. on pyrophoric alloys) are not as reliable as are those drawn directly from Mr. Johnstone's experience. But in the line of the mantle industry and the manufacture of electric lamp filaments the descriptions of commercial practice are particularly complete and satisfactory. Mr. Russell's chapter on Radioactive Substances is also cleverly written. The book, as a whole, contains an unusual amount of scarce information.

* * *

Chemical Constitution and Physiological Action. By Prof. Dr. Leopold Spiegel. Translated from the German by C. Luedeking and A. C. Bolston. 12mo, 156 pages. Price, \$1.25. New York: D. Van Nostrand Co.

This is a serious attempt to collate what is known of the relations between chemical constitution and physiological action, in order to provide a basis for rational scientific medical treatment. After a chapter of general considerations, in which the subject is discussed from a very broad point of view, there are 20 pages given to the consideration of various inorganic compounds and the rest of the book to organic—20 pages to the aliphatic series, 17 pages to the aromatic series, and 70 pages to nitrogen compounds. The odor and taste of these medicines are not considered, but only their medical effects as related to their chemical structure. The work was well worth translating for the benefit of medical students and progressive practitioners.

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BOOK REVIEWS.....

Industrial Conditions After the War

A rare, a magnificent, opportunity is afforded students of political economy, to answer the great question, what will be the economic and financial conditions in the countries of the world after the war. It is a problem to which many are addressing themselves. Our captains of industry have been addressing themselves to it, not with the cocksureness of the type of political economist with which we are all more or less familiar, but rather in the mood of sounding a note of warning. That, in particular, was the attitude of Chairman Gary of the United States Steel Corporation when, apropos of nothing in particular but the conditions and possibilities as he saw them, he gave a long statement to the public on Jan. 8. He does not attempt to solve the problem, but he points out that there are grave possibilities awaiting us, and emphasizes the point that present industrial conditions are absolutely no criterion as to conditions that will prevail after the war.

It is an interesting fact that in nearly all of the many utterances on "After the war—What?" there is a strong appeal that the Government should raise a wall against "dumping." The unanimity and pointedness of the proposal, coming from so many quarters, suggests not so much certainty of thought as uncertainty, in that an anti-dumping arrangement must prove advantageous in one set of conditions, and cannot be harmful should a diametrically opposite set of conditions prevail. It is not necessary, in other words, to prove that the remedy is needed in order to advocate that it be provided. The conclusion can be reached without arranging in advance one single set of arguments leading up to it.

It is elementary, in the dealings between nations, that if one finds itself with more money or credit than others, it tends to spend the preponderance with the others. The war is rapidly increasing our preponderance. Apparently there are many who go no farther than to assume that the adjustment will be in merchandise. Others, who recognize that adjustment can also be made by the flow of capital instead of merchandise, express grave fears that such a flow of capital out of the country will be injurious. In the economic history of the United States the merchandise trade balance was almost invariably against us until 1876, and thereafter, until 1898, the favorable balances were relatively small. For a part of the time the American merchant marine earned some money, to that extent offsetting merchandise imports. During much of the time capital was flowing into the country, and in recent years it has been necessary for us to pay annually hundreds of millions of dollars return upon this capital. This has been done by our exporting more mer-

chandise than we imported. We have prospered with the borrowed money, and have been well able to pay for its use.

In the normal development of any nation such as ours there should be such a period of borrowing, for development purposes, but it seems natural that there should be a time limit to this period. The tenant should not always be a tenant, sending a portion of the fruits annually to the lord of the manor. The war tends to change our position from that of a borrowing to that of a lending nation. The real question is whether the time is ripe for such a change, whether our internal development has proceeded far enough that we do not need the extra capital that has come and is still coming to us.

Political economists recognize a factor known as "the disinclination of capital to emigrate." It is difficult even when all the conditions are known to set a value for the factor, but it exists. The capital will not be drawn from this country unless better returns are promised abroad, and that brings us in substance to the important question what will be the value of goods in different countries. Of course, many other important matters enter, but the flow of merchandise, subject to tariffs, either straight or anti-dumping, hinges upon their relative values. Relatively low-commodity values in foreign countries will exert two influences, to move the commodities to this country, and to disincline our capital to move to those countries. In the event of commodities abroad proving to be cheap, and of their importation being retarded by tariffs, our capital will tend to remain with us. Then, however, comes the more serious question what we shall do with the capital, whether we shall invest it wisely or spend it riotously. Can we spare capital, in view of our own development needs, but if we do retain it shall we use it wisely?

Science and Engineering

Dr. John A. Brashear's charming and sympathetic personality is finely displayed in his presidential address presented before the American Society of Mechanical Engineers last month. He spoke of engineering achievements of centuries long ago—of the pyramid of Cheops and the via Appia which was in perfect repair nearly six hundred years after it was finished. "I have always had the conviction that we give too little thought to the pioneers in any line of research and I have often bowed my head in reverence to those who, with the most limited means and equipment, by patient, persistent plodding, wrested the secrets of nature from their entanglement."

But the principal subject of Dr. Brashear's address was the relation between science and engineering. "Where shall we draw the line between pure and applied science? For myself, I have been unable to find aught but a hazy line of demarkation." When the velocity of the propagation of light waves was determined by scientific reasoning and experimentation of the most refined nature, the process of solving the problem remained for a long time in the domain of the exact sciences as a masterpiece of the human mind. "But who

dreamed to what utilitarian purpose these light waves would be made subservient? The genius of a Michelson carried them into the workshop, thence to the International Bureau of Weights and Measures at Sevres, and gave us a value for the international meter in terms of light waves that will remain absolutely unalterable as long as this old world moves in the lumeniferous ether of the universe." "Getting nearer the utilitarian service of the scientific study of light waves, Dr. Anderson of Johns Hopkins has utilized them in making screws of hitherto unheard-of accuracy." And when in railway shops nuts made by some firms would not screw on bolts made by others, the problem at first baffled the ability of the most prominent manufacturers of tools of precision in the country, but it was solved through the co-operation of a professor of astronomy. And the development of instruments for mechanical measurements to the highest state of precision has been a mighty factor in the development of interchangeable machinery.

And this utilitarian use of science in making possible the construction of accurate screws has again reacted, as it were, and enabled the scientific mechanic to produce a little optical device that rivals, if it does not surpass, the telescope—the diffraction grating. "On the plane surface of its polished plate, made accurate to one-tenth of a light wave, or within one forty-five thousandths of an inch, are ruled more than 45,000 lines between which there is no greater error than one two-millionths of an inch. With this delicate piece of apparatus, made possible first by rigorous scientific research, second by the skill of the artisan, third by a knowledge of and vigorous care to avoid temperature changes, and fourth by the accuracy of the mechanism which includes the accurate screw mentioned above, the astro-physicist has been able to tell us the composition, temperature, and distance of the stars. It is also possible for the physicist, the chemist, to tell us the purity of the material he is called to investigate; indeed, it makes itself subservient to many phases of engineering in the domain of metallurgy. And the end is not yet. Where can we draw a sharp line of demarkation between pure science and its relation to any and every form of engineering?"

Hydrolysis of Alkali Cyanide Solutions

It occasionally happens that some of the refinements in a metallurgical process are deferred for study until long after the essential features have been made commercially successful. This may be because the refinements were not early appreciated, or because they are not forced on the attention through economic necessity. In the course of time, however, incidents arise which direct attention to points that have escaped critical thought.

A case in point seems to be the recent study that has been given to the part played by hydrolysis in the consumption of cyanide in the treatment of gold ores. It has long been known, of course, that the apparent requirement of cyanide was far in excess of that indicated

by the dissolution of the precious metals. Previous study also has been given to cyanicides of various kinds, and means have been devised to minimize their effect. Nevertheless, when all the recognized causes of cyanide consumption have been considered, we are still confronted with the fact that a large item of loss remains unaccounted for. The suggestion is now made that this loss is due to hydrolysis of the alkali cyanide into caustic alkali and hydrocyanic acid, and the volatilization of the latter from the solution.

In our synopsis of current literature in this issue we give abstracts of two important papers bearing on this subject, by H. A. White and H. M. Leslie of South Africa. In our issue for Dec. 15, we reviewed Mr. Leslie's United States patents for a system of cyaniding designed to obviate the loss due to hydrolysis. All of these are deserving of the careful consideration of cyanide metallurgists. If, as Mr. Leslie believes, a loss of from 30 to 50 per cent of the cyanide used is to be ascribed to hydrolysis, and a substantial portion of this loss can be prevented, the subject is of vital importance. South Africa consumes roughly 5000 tons of cyanide per annum; the United States, 2500 tons; Canada, 1200 tons. Mexico is an uncertain quantity, but in normal times would show a large consumption. Even a small percentage saving on this combined tonnage would be an important item of economy. We invite discussion of the subject.

English in Mining Schools and Universities

The impression grows that English should constitute almost a major course in the curricula of our schools of mines. One has but to read examination papers, theses, and even business letters written by undergraduate mining students to be convinced of this need. That there is a lack of proper preparatory work in high schools there is no doubt; but the college cannot take refuge in this excuse and escape its duty to those who are graduated with baccalaureate or professional degrees, presumably as men of some cultural attainment as well as technical knowledge.

Among students there is a strange antipathy to the study of English as something non-essential and of trifling importance. This, however, makes it more imperative for the college faculty to prescribe what is best. Perhaps it points also to a need of presenting the subject in a manner appropriate to technical students, so that they will appreciate its importance and cease to regard it as a side issue of no consequence.

It should not be difficult to impress the student with the fact that his written work is his personal representative and often the sole medium by which he is judged; that the written or printed word is subject to closer scrutiny and more critical analysis than speech; and that glaring errors in composition and spelling stand out so prominently as to distract the attention of the critical reader. It is not necessary that the engineer acquire a brilliant style or fanciful diction, but his writing should be characterized by simple, precise, and logical expression.

There is a curious inconsistency in this failure of the student to appreciate the value of English. Whereas an engineer practices exact science, using instruments of accuracy and precision, he has strangely overlooked the necessity of familiarizing himself with the equally exact, precise, and accurate tools of expression. Further, as a professional man, the engineer is expected to embody culture as well as technology, and the least he can do in adorning the latter with the former is to have a good working knowledge of English.

Several years ago an official of a large company took the trouble to investigate the training and ability of a number of engineers by examining critically three hundred of their reports on mining properties. Among graduates from technical schools only, he discovered almost unbelievable ignorance of the principles of English composition; and it was only in the work of those men whose engineering training had followed a liberal arts or classical education that culture and refinement were shown in the correct use of our language. In commenting on this striking discovery, the investigator said: "If clear writing is necessarily preceded by clear thinking, then a large body of technically trained men is hopelessly lost in the fog."

We are aware that the teaching of English has been receiving more attention in mining schools during the last few years; but there is still room for improvement. The subject must receive special attention; it cannot be handled satisfactorily by the other instructors, although they can be of benefit in supporting the special work. We can imagine that difficulty arises in finding time and place for the course in a crowded curriculum, but this will have to be done until students come to college with better training. Two alternative solutions are to lengthen the course of study or make mining engineering a post-graduate course, both of which seem of doubtful propriety at the present time.

Yet it would be unfair to speak of this problem as though it concerned mining schools alone. As a matter of fact it apparently concerns with few exceptions all our higher institutions of learning. No less a competent and well-informed observer from the engineering field than Mr. Arthur D. Little, made the following pointed remarks the other day in the symposium on the university and the industry before the New York Section of the American Chemical Society (page 941 of our issue of Dec. 15, 1915): "The business man seldom has at his disposal any more potentially efficient tool than the English language, but in his hands it is a tool which is often rusty and very seldom so keen and highly tempered as to be capable of rendering its highest service. The fault of this is largely with our universities, and the remedy, so far at least as their own students are concerned, is in their hands. Our great institutions of learning are every day disgraced by the inability of their recent graduates to make a concise and convincing oral statement of a series of facts, to prepare a well-organized and adequate report, or even to write a graceful and informing letter."

Reader's Views and Comments

A Board that Receives No Pay and Provides for All Its Own Expenses

To the Editor of Metallurgical & Chemical Engineering:

SIR:—In spite of the extraordinary extent of the field now covered by governmental activities, intelligent people still remember at times that a fundamental function of a government is to provide means for repelling foreign aggression. While immense amounts of the taxpayers' money are now spent in paying employees by whose activities many citizens are benefited but remotely or not at all, we are all vitally interested in the defense of our lives and property.

With this in mind, the following statement of Dr. L. H. Baekeland (METALLURGICAL & CHEMICAL ENGINEERING, Dec. 15, 1915, page 944) is almost incredible:

"No member of the Naval Consulting Board draws any salary nor gets any remuneration from the Government.

"We all pay our traveling and hotel expenses and each member feels that if he can give his time, free of charge, to the Government, he can still better afford to pay his own expenses.

"This program is carried out so scrupulously that even the cash for the purchase of stationery and printing is furnished by members of the board, who are monthly assessed among themselves."

It is surely bad enough that the politicians whom we allow to govern us should take our money for all sorts of unnecessary expenditures without putting us to shame by letting a group of scientific men pay for the privilege of working for our defense.

FRANCIS A. J. FITZ GERALD.

Niagara Falls, N. Y.

Two Instructive Accidents from Chemical Engineering Practice

To the Editor of Metallurgical & Chemical Engineering:

SIR:—The two accidents described in the following notes may be of interest to your readers. They have occurred under my observation.

A MISAPPREHENSION AS TO THE EFFECT OF CHANGING THE CENTER OF GRAVITY

A few months ago, at one of the largest chemical manufacturing concerns in the country, a peculiar accident occurred, illustrating the result of not taking into account the shifting of the center of gravity in a cylindrical vessel standing at an angle with the horizontal, while being emptied of a liquid.

In this case, a standard-gage railroad tank car, loaded with acid, was being placed upon a car float preparatory to being ferried across a stream about 1 mile wide. The tide being out, the float was several feet below the level of the tracks, and the hinged "bridge" which formed the connection from land to float stood at a considerable down-grade. As the car was being handled

over this bridge, the knuckle pin of the coupler broke and the car ran away (the brakes not holding on the steep grade) and passed upon the car float, traversed its entire length, crashed through the 12-in. x 12-in. buffer timber at the end of the track, demolished the float captain's cabin and only came to rest when one of its trucks was overboard in 12 ft. of water, and with one end of the tank projecting over the end of the float.

Those in attendance discussed the possibility of the tank dropping into the water, but reasoned that since it had come to rest, if the remaining truck were securely lashed to the end of the car still on the float, it would provide counterweight sufficient to make the tank stable enough to permit the float being moved to an adjoining wharf where provision in the way of storage tanks and compressed air were available for unloading the acid from the car. This shift was made, and the unloading progressed without incident until the liquid reached a level indicated by the dotted line in Fig. 1, when, without warning, the tank suddenly tilted over the end of the float, landing end-down in 20 ft. of water, and taking the truck along with it.

Fortunately no one was injured during the affair, and after a derrick was procured, the unloading was continued by making additional holes in the end of the tank (which projected above the water) for the application of compressed air and acid piping. The tank and trucks were recovered. Only a slight amount of acid was lost.

MISJUDGING THE CAPACITY OF A CRANE

A few months ago the writer was engaged in the installation of an iron ore concentrating machine, and among other appliances had a locomotive crane whose capacity, or overturning moment, was rated by the builders at 150 ft.-tons.

One section of the apparatus weighed 6 tons, and the nearest point we could get with the crane called for a radius of lift of 24 ft., or what would amount to an overturning moment of 144 ft.-tons. As the casting in question was loaded on a flat car, we placed the crane as near as possible to the point it would occupy when landing the casting and placed the flat car back of it, so that all we would have to do would be to raise the casting from the car, swing the crane through an arc of about 180 deg., move slightly ahead, and land the casting. The crane being fitted with rail clamps, we adjusted these but did not think it worth while to place out-riggers under the frame, as the load was within the specifications.

However, much to our surprise—and regret—when the crane had swung about 90 deg., it suddenly turned over, dropping its load, which narrowly missed two workmen. Fortunately no one was injured except the craneman, who suffered a sprained ankle after jumping to the ground, and tripping on an obstruction while running to a point of safety.

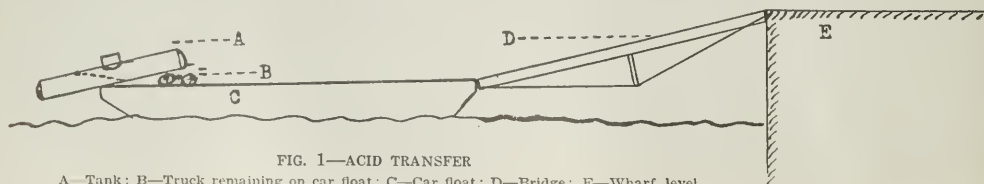


FIG. 1—ACID TRANSFER

A—Tank; B—Truck remaining on car float; C—Car float; D—Bridge; E—Wharf level

In pondering over the mishap, it suddenly occurred to us that the crane was standing on a sharp curve—22 deg.—was swinging the load toward the center of this curve and the super-elevation of the outer rail was sufficient to shift the center of gravity from the track center toward the inner rail, thus reducing the overturning moment on that side an amount sufficient to tip the crane over.

A serious oversight in the construction of this crane was brought out in this accident, this being that the boiler was not anchored to the frame, with the result that when the crane tipped, the boiler shifted badly breaking the 2½-in. steam pipe near the boiler, and the escaping steam would undoubtedly have scalded the operator had he not been nimble enough to avoid being caught between the boiler and the levers. All owners and users of these cranes, whether engaged in bucket or actual crane service, should have this point examined at once, and suitable anchorage provided for the boilers should it be found lacking, as a capsizement is liable to occur at any time, and the results may not be as fortunate as was the case in the accident above mentioned.

Low Moor, Va.

J. W. RUPERT.

Carrie Jane Everson and the Flotation Process

BY H. C. PARMELEE

When the process of concentration by flotation came into prominence in the United States several years ago the name of a woman, Carrie J. Everson, became generally known to engineers through her early contribution to that art which is now so widely practised. This remarkable woman had twice patented her ideas on flotation: first as a resident of Chicago (348,157, Aug. 4, 1886), and later from Denver (471,174, March 22, 1892). The latter patent was issued jointly to Charles B. Hebron and Carrie J. Everson.

The fact that Mrs. Everson was once a resident of Denver aroused among the engineers of that city a special interest in her identity and whereabouts. The matter was frequently a subject of casual conversation, and the suggestion was often made that a systematic search should be undertaken to ascertain whether the woman were still alive, and if so, to learn more concerning her work and the incidents that led to her discovery. The latter point was of particular moment, since a legendary account credited "Miss Everson, a Denver school teacher," with discovering the phenomena of flotation "while washing greasy ore sacks in her brother's assay office in Denver." Since no member of the mining and metallurgical fraternity in Denver could recall an assayer by the name of Everson, this story was open to doubt and offered no probable clue to the truth.

In any event, no serious effort was made to ascertain the facts until, in July, 1915, the Colorado Scientific Society appointed a committee for that purpose, consisting of George E. Collins, Phillip Argall and Howard C. Parmelee. The society's object was twofold: first, to determine beyond question the woman's part in the patented discovery, and second, to consider the advisability of proposing some form of memorial in her honor. One of the first results of the committee's work was the discovery that Mrs. Everson died at San Anselmo, Cal., Nov. 3, 1914, a fact that caused keen regret that the society's search was not undertaken at an earlier date, when the results might have been of more than historical value, not only as relating to Mrs. Everson, but also to the metallurgical industry. It can be imagined, for instance, what intense interest would have been aroused by her appearance as a witness in the hotly contested suits over the validity of certain flotation patents, for Mrs. Everson

was still alive and active during the time of the litigation between Minerals Separation, Ltd., and the Butte & Superior Copper Co. And it may be more than idle speculation to consider what might have been the effect of her testimony in establishing the prior state of the art as disclosed in her own patents.

Investigation by the Colorado Scientific Society

The society's committee began its investigation by endeavoring to locate the witnesses to the Denver patent, and one Thomas F. Criley, who was credited with an early attempt to introduce the process at Baker City, Ore. As a result of searching the Denver city directories for 1885 to 1915, inclusive, one of the patent witnesses was found, Mr. E. A. Fay, in whose family Mrs. Everson had at one time lived. Many interesting details were disclosed in this directory search, among which was an inconspicuous item in 1891, "Hebron-Everson Process, Room 22, 1452 Lawrence St.," which was eloquent of the hopes and ambitions of the early promoters.

From Mr. and Mrs. Fay we ascertained many interesting facts regarding Mrs. Everson, and particularly that she had removed to California about 1909, where her son, John L. Everson, was supposed to be living. While this clue was being followed the writer had what he supposed was only a casual conversation with Mr. Arthur Chapman, a special writer for the *Denver Times*, giving him the story of the Everson matter as far as it had been developed. With true newspaperman's instinct, Mr. Chapman scented a good story and prepared an elaborate article for his paper. Among other features he emphasized the fact that Mrs. Everson's present whereabouts were unknown. The story immediately attracted attention throughout the West, and as a result of it we received a number of letters from Mrs. Everson's former acquaintances, giving various bits of information. Among others came a letter from Miss Anna E. Watson, of Pueblo, Col., who had formerly worked with Mrs. Everson as a nurse in Denver, advising us that Mrs. Everson's last known address was San Anselmo, Cal. At the same time the *Rocky Mountain News* located John L. Everson at the same address. Mr. Everson was immediately communicated with and has given us practically all the information available regarding his mother's work. The following notes are based on his correspondence.

Biographical Sketch

Carrie Jane Billings was born at or near Sharon, Mass., about Aug. 27, 1842, of early Pilgrim ancestry. About 1851 she removed with her parents to Springfield, Ill., where she received her early education, "the best possible at that period." On Oct. 3, 1864, she was married to William Knight Everson, a Chicago physician. Five children were born, of whom the only survivor is the son mentioned above. Dr. Everson was very successful in his medical practice, and Mrs. Everson took a deep interest in his work, studying various branches of science and becoming proficient in chemistry.

About 1878 Dr. Everson became interested in mining ventures, and is reported to have invested \$40,000 in the Golden Age Mining Co., of Brick Pomeroy fame. This echo of the past will recall to some who are familiar with the early history of mining in Colorado other incidents in the career of that illustrious promoter, Brick Pomeroy. Dr. Everson soon realized that his investment was ill-advised, and he abandoned his interest in it. Mrs. Everson, however, is reported to have hoped that something might be saved from the wreck, and began the study of mineralogy in order to

fit her for technical investigations. Her son states that he can distinctly remember seeing her work in the laboratory, grinding ore with mortar and pestle and submitting the powder to microscopical examination, using Dr. Everson's instruments.

Some time in 1879-1880 Dr. Everson took a trip to Mexico, possibly for his health, since it is known that his health failed about that time. During this absence Mrs. Everson discovered what she then termed the "chemical affinity of oils and fatty substances for mineral particles." Her method of demonstration is disclosed in the Chicago patent, reference to which has already been made in this journal. On Dr. Everson's return from Mexico the two engaged in research for the purpose of perfecting Mrs. Everson's discovery. Dr. Everson abandoned his medical practice and devoted his resources to the work, with the result that the patent was finally obtained. Efforts were made to interest mining men in the process, but with little success, and the Eversons' financial resources gradually ebbed. Finally, on Jan. 20, 1889, Dr. Everson died at Denver, and his wife was left to care for herself and young son. As a means of livelihood she took up obstetrical nursing and practised this profession for many years in Denver.

At this juncture she made the acquaintance of Thomas F. Criley, who became interested in the process. He and John L. Everson went to Silver Cliff, Col., and secured the

use of an abandoned, dilapidated ten-stamp mill for experimental purposes. An 800-gal. tank was constructed, with revolving paddles and an adjustable horizontal partition. The partition was made of two pieces, hinged in the middle so that the leaves could hang vertical or be raised to a horizontal position. In carrying out the test, the tank was filled with water, and after the ground ore and oil were thoroughly mixed the mass was placed in the tank. The paddles were revolved so as to agitate the mixture, and after thorough agitation the dividing partition was raised to separate the floating mineral and oil from the water and tailing. The latter was removed through a gate in the bottom of the tank. The oily concentrate was collected in iron pans and placed in the fire-box of the boiler in order to burn off the oil. Mr. Everson reports that the ore thus treated was quite coarse, over half of it larger than 40 mesh. The concentration ratio was about 4:1, but for one reason or another the general result was not successful. Mr. Criley then tried to interest people in Baker City, Ore., and Mrs. Everson went there with him for that purpose, but was not successful.

Introduction of Hebron-Everson Process

The advent of Charles B. Hebron on the scene occurred about 1891. He is reported to have been a chemist from New York, claiming to have had experience in ore concentration. It appears that he

had little faith in the use of oil, but when Mrs. Everson explained that she had also made use of lamp-black and other materials to effect flotation he showed more interest. Through his instrumentality funds were secured for getting the second, or Denver, patent, which discloses the use of "charcoal, coke, lamp-black, plumbago, any sort of friable vegetable fibers—such as bark, moss, straw, cotton, wool—also sulphur (sublimed), aluminum trihydrate, hydrated lime sulphate, sodium oleate and other cheap salts of sodium, also the cheap metallic sulphates and oleates" as "buoyant materials."

Mr. Hebron secured funds for experimental work and gained the co-operation of a Mr. Pischel, of Denver, in consideration of an interest in the patent. They carried on some work in an old building in Valverde, near Denver, where Hebron set up a sluice box about 60 ft. long, 6 ft. wide and 18 in. deep. Cleats were nailed on the bottom of the box at intervals of 2 ft. to produce gentle ripples on the surface of the water running through the box. An adjustable

gate at the lower end of the sluice permitted regulation of the surface disturbance due to the cleats. The mixed ore and buoyant material was gently sifted onto the surface of the water at the head of the box, and by the time it had reached the lower end the separation of mineral and gangue was complete and the two products could be



CARRIE J. EVERSON

Photograph taken shortly after her marriage in 1864



CARRIE J. EVERSON

Photograph taken when she was a nurse in Denver

collected separately.

After a few tests the process seemed to be successful, and the principals were elated at the prospect. Here, however, another touch of human nature entered into the misfortunes of the Everson process, for "Mr. Hebron and Mr. Pischel quarreled over the millions each was to make, and the whole matter was abandoned."

As far as we are able to learn, the succession of disheartening failures now caused Mrs. Everson to abandon hope of ever bringing the process to a successful issue, and she took no further active steps in that direction. In 1892 she accepted a position as visiting nurse for the Denver Flower Mission and continued in that position until 1906. At that time she was engaged on the staff of the State Industrial School for Girls, near Morrison, Col., and remained there until she removed to California in 1909. She died at San Anselmo, Nov. 3, 1914, and was buried in Mount Tamalpais Cemetery.

Inventor's Confidence Unshaken

Although Mrs. Everson apparently abandoned all hope of ever commercializing her inventions, she is reported to have been confident that some one would at some time do so. She did not learn of the success of flotation until after her patents had expired, and at that time it was too late for her to secure any advantage. Her son states that she always felt that

a combination of flotation and cyanidation would prove profitable—a prophecy that is about to be fulfilled.

In personality Mrs. Everson is described by her friends as a quiet, kindly, self-sacrificing woman who devoted her life to those less favored than the majority. All who knew her bear testimony to her sterling character and worth and her happiness in being of service to others.

The accompanying photographs show her first as a young woman, shortly after her marriage, and later as a nurse. The former was furnished by her son, and the latter by Mr. Fay. As far as we are aware, these are the only photographs extant. Mr. Everson states that his cottage at San Anselmo was destroyed by fire in December, 1910, at which time all of Mrs. Everson's patent papers, contracts and correspondence were destroyed. Enough facts have been established, however, to set at rest the rumors, legends and apocryphal stories regarding her life and work.

The question has been asked repeatedly, Why was not Mrs. Everson's work appreciated in an earlier day before the patents expired? For answer there may be several reasons. In the first place we may imagine that the process was ahead of its time as far as metallurgical necessity was concerned, and therefore was not appreciated. Again, we may easily conceive that it was passed by as "a crazy notion" that did not appeal to the practical men of the time. And finally, with all due respect to its inventor, we can readily believe that there were some who scoffed at the process because it was "discovered by a woman." On the other hand, there may be found a reason in the fact that the second patent departed from the fundamental ideas of the first, viz., the use of oil and fatty substances, and substituted lamp-black and a long list of other buoyant materials. In other words, the Hebron-Everson patent does not now seem to be as important as the original Everson patent, and it may have been a mistake to admit the innovations insisted upon by Hebron, even though they were first conceived by Mrs. Everson. However, the fact remains that Mrs. Everson stands in the position of an originator of the process of concentrating mineral by oil flotation, and while no financial advantage accrued to her from her discovery, she is generally credited with having disclosed in 1886 all the essential elements of the process as practised to-day.

The Iron and Steel Market

The slight lull that seemed to develop in the steel market in the second half of December proves to have been of no significance. In so far as it represented a holiday slackening its influence disappeared before the normal time, for the characteristic holiday lull is supposed to extend to the middle of January at least, an evidence of the holiday influence being quickly shaken off appearing in the fact that several important advances in finished steel prices occurred the first week in January. In major part, however, such quieting down in steel buying as occurred was due to the fact that the market was fully sold, indeed oversold. The mills cannot indefinitely continue to sell week by week much more material than they produce, nor can buyers indefinitely buy in such manner.

In the case of nearly all steel interests the December bookings of actual shipping orders made a new high record, the bookings being chiefly in the form of specifications against contracts, and chiefly contracts written long ago. Sometimes the passage from one calendar quarter to another effects a decided change in the rate of specifying, the contracts coming into force being at materially higher prices than those just expired. In

this case, however, steel price advances have been so rapid that the current market is much higher than the level at which many contracts for the present quarter were written, and specifications this month are likely to prove very large, possibly as large as in December. Taking the mills as a whole it will not be until the second quarter of the year that they will be given much opportunity to catch up in their rolling schedules, while the outlook is that they will never catch up until consumption decreases.

Since early in December shipments of steel from the mills for direct export have been greatly curtailed, chiefly through the action of the railroads in placing embargoes until the large volume of material in cars at eastern terminals has been moved. The net effect of the embargoes has been reduced, but only slightly, in the past fortnight. During this curtailment in export shipments from mills the shipments to domestic buyers are correspondingly increased, and the material is all welcome. A still greater scarcity of steel in the domestic market is to be expected when export shipments are increased.

Chairman Gary of the United States Steel Corporation on Jan. 8 made a lengthy statement to the public, through the medium of the daily press, expressing the belief that there was great expansion and the fear that there was also great inflation. He pointed out that prosperous conditions were assured only while the war lasted, there being grave dangers thereafter, and stated that he expected the war to end sooner than most people expected. As to steel prices, they were high, but the buyers frequently caused advances themselves, and steel price advances were probably not ended.

During the first week in January the following advances in steel prices occurred: Bars, plates and shapes, \$1 a ton; standard steel pipe, line pipe and oil country goods, \$1 to \$2 a ton; steel boiler tubes, \$4 a ton; blue annealed sheets, \$3 a ton; railroad and small spikes, \$3 a ton; cold roll strip steel, \$5 a ton; rivets, \$2 a ton, and bolts and nuts, 10 per cent.

Steel ingots are being produced at the rate of 40,000,000 or 41,000,000 tons a year, and the new construction of open-hearth steel furnaces, including two cases of duplexing plants, involves an addition of between 10 and 11 per cent to the capacity. More than half the new construction will likely be completed by July 1. There appears to be new construction in finishing departments sufficient to prevent a surplus of unfinished steel. Ten blast furnaces are being built or are definitely projected, representing about one-half the raw material requirements of the additional open-hearth capacity. As pig iron has already become scarce, and both pig and scrap prices have advanced sharply in the past two months, there are possibilities that the alignment of the new construction program now being worked out will produce a definite shortage of pig iron.

The steel mills are now booking very little business in the form of open contracts for specification in future. Specific orders they will accept for such delivery as they can compass. The total of specific and contract commitments represents an average of fully six months of full production, but in some lines the commitments are much greater than in others, being greatest in rails and large steel rounds, rolled alike on rail mills, in plates and in bars, and smallest in tubular goods and wire products, which are customarily not sold far ahead. The volume of wire business on books is unprecedentedly large for the product.

The United States Steel Corporation's unfilled obligations at the close of December were reported on Jan. 10 to have been 7,805,220 tons, representing an increase of 615,731 tons during the month. The normal rated capacity for the month, in steel products for sale,

may be taken at 1,220,000 tons, so that the increase in unfilled obligations during the month was fully 50 per cent of the capacity, while the shipments were slightly in excess of rated capacity, making the bookings more than 150 per cent of the capacity. A large part of the increase in obligations, however, was doubtless in tin plate, which is sold under contract for the entire season of 1916.

Pig Iron

Pig iron has been quiet since the first of the month, as to the actual turnover, but the market is fundamentally very strong, and the sharp advances during December, averaging fully \$1.50 per ton, do not seem to have left the market top heavy in any sense. The furnaces are well sold up for many months and shipments are readily taken. The market is quotable as follows: No. 2 foundry iron, delivered Philadelphia, \$19.75 to \$20.25; f.o.b. furnace, Buffalo, \$18 to \$18.50; delivered Cleveland, \$18.80; f.o.b. furnace, Chicago, \$18.50; f.o.b. Birmingham, \$15 to \$15.50; f.o.b. valley furnaces, 95c. higher delivered Pittsburgh. Bessemer, \$21 to \$21.50; basic, malleable and forge, \$18 to \$18.50; No. 2 foundry, \$18.50 to \$19. Several foreign producers of ferromanganese have withdrawn their contract quotation of \$110, Baltimore.

Steel

The market for soft steel billets continues to be very narrow, as the regular consumers are fairly well covered by contracts, at much lower than present asking prices, about \$32 to \$33 for Bessemer and \$35 for open-hearth, and in view of prices obtainable for finished products it is only occasionally that a buyer could afford to pay the prices asked. Sheet bars are nominally quoted at the same level as billets, with consumers covered by contracts. Ordinary forging billets are scarcely quotable, but forging or rolling billets to conform to war steel specifications are bringing \$50 or more. Rods are probably within the range of \$40 to \$44, Pittsburgh.

Baltimore Meeting of the American Institute of Chemical Engineers

Inclement weather spoiled slightly the excursions on the first afternoon of the Baltimore meeting (the eighth annual meeting) of the American Institute of Chemical Engineers. But it could not detract from the success as a whole. There was an unusually good attendance at the first session, held on the morning of Wednesday, Jan. 12, at the Hotel Emerson, some 60 or 70 members and guests being present. Sickiness, unfortunately, prevented the president, Dr. George D. Rosengarten, from being in the chair. In his stead Past President Dr. Samuel P. Sadtler of Philadelphia acted as chairman.

A cordial welcome was extended to the Institute by the Deputy Comptroller of Baltimore and the reply was made by Professor Withrow, who emphasized that the city of Baltimore had always been a center of chemical activity. The annual reports of the officers, the council, and the different committees were presented, which showed the institute to be in good financial condition and quite active through its various committees.

The professional session which followed brought two very interesting papers. The various factors which affect and influence the development of the chemical coal-products industries in this country were discussed by Mr. H. W. Jordan of the Semet-Solvay Co., with great lucidity and often with a fine, quiet humor. Dr. W. F. Rittman of the Bureau of Mines followed with a discussion of the chemical engineering problems of

the cracking of petroleum, speaking with characteristic directness and impressiveness.

Mr. Jordan showed convincingly that if the United States is to have a complete industry in the manufacture of the many different products derived from coal, the following essential conditions must be fulfilled: co-operation of the American acid and alkali manufacturers with the coal-tar industry; co-operation of the American consumers with the American producers through long-term contracts to assure the American market; establishment of the industry on a peace-scale big enough to make it a fundamental factor in national defence; establishment on a profitable commercial basis of the manufacture of nitric acid, by fixation of atmospheric nitrogen; nationalization or rather internationalization of the industry to insure a balanced world market for all by-products; development of a system of twentieth century common school and technical school education, and maintenance of a rational tariff.

The paper was discussed by Messrs. Frerichs, Withrow, and Prochazka who gave reminiscences of early American achievements in the chemical coal-products industry.

Dr. Rittman, in his paper on the cracking of petroleum, said that the variables in the cracking reactions are temperature, pressure, time, concentration (mass action) and contact surface (catalysis) and that the engineering apparatus must be designed to fit these variables. The source of the oil is not of primary importance, but the desired end products are. Dr. Rittman dealt successively with the production of gas, of gasoline, and aromatic hydrocarbons, discussing in each case demand, supply, and future. Pictures and lantern slides were shown of the bureau's "Plant No. 1," in Pittsburgh, which produces 500 gal. benzol and 500 gal. toluol per day. Plant No. 2 which was started last week very successfully, seems a great improvement. Six or seven other plants are being erected or projected.

In the discussion Dr. Cushman and Dr. Frerichs asked some questions which were answered by Dr. Rittman.

At the Wednesday evening session the first paper was read by Dr. A. D. Little of Boston. This was a brilliant discussion on wood waste utilization, showing that the potential profits in utilizing this waste would be much greater than the actual profits in the present industry. When this waste is used as raw material an enormous by-product industry can be formed. The technical staff of Dr. Little's organization made a careful investigation of this problem on a large scale, over a period of eight months. They found that with a cut of fifteen billion feet of yellow pine the Southern lumber industry now wastes raw material which if utilized would yield daily 40,000 tons of paper, 3000 tons or rosin, 300,000 gal. of turpentine, 600,000 gal. of ethyl alcohol, besides fuel to meet all requirements of the industry. Dr. Little discussed the recovery of these products. This very able paper will be published in full in our next issue.

The next paper was read by Mr. W. S. Landis on the production of ammonia from cyanamid. This paper will be found published in full elsewhere in this issue (page 87).

The last paper was read by Mr. Maximilian Toch on the barium industry. Mr. Toch discussed the various barium salts and emphasized the necessity of a protective tariff.

A report of the other sessions and social functions of the convention, as well as publication in full of several of the other papers read at the meeting, must be reserved for our next issue.

The Rubber Industry—II

BY ANDREW H. KING

In my previous article I discussed some of the more important points in regard to the production of rubber, its properties, the nature of its molecule, proposed methods for its synthesis and also reviewed the various theories of vulcanization. In the following article I will outline factory practice in general.

Washing

After the arrival of crude rubber at the factory, the first operation which it undergoes is washing. While plantation rubbers are shipped washed and dried, many African, South American, and other varieties arrive at the factory in a dirty condition. African rubbers are particularly offensive. Besides certain putrefying plant juices which are usually present, sticks, stones, clay, etc., are often to be found.

The dirtier grades are best washed in a machine much resembling the beater of the paper mills. The better grades are washed directly on the rolls, with or without previous steeping in warm water. The rolls are corrugated, usually two in number, and a strong stream of water is thrown down between them during the operation. The rubber is passed through the rolls until clear and thin. Fig. 1 shows a modern three-roll washer. It differs from the usual two-roll type in the addition of an extra roll. This gives it an increased capacity which is said to be double that of the common type.

Drying

The wet sheets as they come from the wash room are dried either by vacuum dryers or by hanging in a warm room. Some companies do all their drying by vacuum, while others claim that the heat is injurious and use the older method. Sometimes both methods are used, it being the custom to hang everything strong enough to support its own weight, and vacuum dry the remainder. When hanging is resorted to, the sheets are hung in rows in a steam-heated, well ventilated room. This room must be darkened so as to retard oxidation. The temperature is ordinarily kept at 27 deg. C., but this is often found a little high for the cheaper grades of rubber. With good ventilation, drying is completed in three or four days, after which the rubber is milled, sheeted, and rolled up for compounding.

Compounding

As was stated previously, rubber has a reticular or network structure. It is this fact which makes com-

pounding possible. Each little loop of the net holds its quota of material. Obviously the larger the volume of compound added the farther apart the rubber nuclei are pushed, and the more strain is placed on the little connecting filaments. Therefore, the stiffer and less elastic becomes the product. Primarily compounding is based on volume percentage. Therefore, the more light pigment present the harder is the article. Hard valves almost always contain considerable quantities of such fillers as fossil flour, aluminium flake, etc. By analogous reasoning we see that heavy pigments which have a small relative volume give the opposite properties. Snappy elastic articles are produced by the aid of such fillers as litharge, barytes, zinc oxide, etc.

In compounding, as in the other branches of the industry, the price factor is paramount. It is the aim of the rubber chemist to always use material of just the necessary quality but no better. It is an economic sin to use Para rubber where shoddy will do just as well. The uninitiated must not get the idea that raw rubber properly vulcanized is the very best. The principal factor in determining a compound is its intended use. The degree of elasticity, toughness, strength, and resistance to abrasion must all be known before a satisfactory compound can be prepared. These properties all depend to a greater or smaller extent on the material used in compounding.

A constantly increasing variety of compounding materials finds application. There is little change, however, in the number of inorganic fillers. Very few materials are added just to fill up space. Most of them impart certain definite properties which may be used as a basis for classification, as follows:

Fillers Only.—This group embraces the various grades of rubber substitute, shoddy, ground rubber waste, and also certain inert mineral fillers such as whiting, barytes, and to a certain extent zinc oxide.

Rubber substitutes are the products derived from various oils such as rape, corn, linseed, etc., by one or the other of the following methods: First, sulphonation, the oil is boiled with sulphur; second, it is treated with sulphur chloride; or third, it is blown with air while at the boiling temperature or oxidation is effected by other means. Practically all white substitute is made by the use of sulphur chloride. Quite frequently sulphonated oils are blown. Substitute when properly prepared has a slight amount of "give," but almost no cohesiveness. It mixes easily in a compound and its purpose is simply that of a cheapener.

Shoddies will be discussed later.

Those Having a Hardening or Toughening Action.—Fossil flour, aluminium flake and other low-gravity materials act as tougheners, as explained in the foregoing. Zinc oxide, lithophone and calcined magnesias also have this property. Because of this function it is customary to find even 50 per cent or over of zinc oxide in the tread of an auto tire. Lime and litharge have a decided hardening action. It is not uncommon to find around 25 per cent litharge or 15 per cent lime in a hard valve.

Those Giving Dense, Non-Porous Mixtures.—Under this head come those materials which find application in articles which have to withstand water, steam, air, etc., under pressure. Mineral rubber, which belongs to the bitumen class, finds perhaps the greatest use in this respect. Tar and paraffine also are used.

Accelerators.—Those substances which hasten vulcanization are known as accelerators. It is quite obvious that the addition of a substance which cuts down the period of vulcanization increases a factory's output and also the profit. Their action is catalytic and they simply hasten the reaction between sulphur and rubber. Under this head come various oxides, the most important

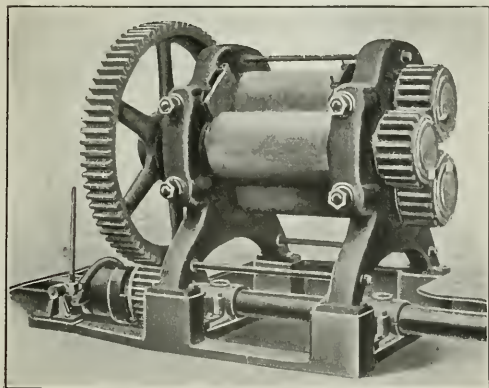


FIG. 1—THREE-ROLL WASHER

being lime, magnesia, litharge and zinc oxide. Their relative accelerating power is shown by the order in which they are named. Lime finds considerable favor in this country, while the European preference is mostly for magnesia. Litharge is perhaps the most used of any. Lately organic accelerators have come into prominence. Dittmer claims that all organic bases having dissociation constants greater than 10^{-4} act as accelerators, regardless of constitution. To date the most important published ones are: Tetramethylenediamine, urea derivatives, carbon bisulphide addition products and piperidine.

Those Having a Softening Action.—Various oils, such as rosin and palm, are sometimes added in small quantities to soften a stiff stock for sheeting or for use on a tube machine. Heavy mineral oils, such as vaseline, are also used. It is the aim to keep away from saponifiable oils as much as possible.

Those Having a Sticky Tendency.—In building up articles such as tires, where many layers of thin sheets are used to make up a section, it is quite necessary for proper vulcanization that these layers stick tightly together. It is therefore often necessary to increase the stickiness of uncured stock by the addition of such substances as crude turpentine, tar, various pitches, etc. This factor becomes of more importance in the manufacture of frictions; i.e., fabric coated and impregnated with rubber compound.

Pigments.—The most important white pigments are lithophone and zinc oxide. In preparing a white stock it must be remembered that no lead compounds can be used since lead sulphide (black) is formed on vulcanization. The chief red pigments are: Crimson antimony sulphide, mercuric sulphide or vermilion, iron oxide and certain lakes. Antimony sulphide is much used in the production of non-blooming articles, such as auto-inner tubes of the best grade. By blooming we mean the tendency for the free sulphur to come to the surface and give a thin, dirty white scum of colloidal sulphur. Other pigments are prussian and ultramarine blue, chrome yellow, chrome green, etc.

As would be expected, compound receipts are quite valuable, and rubber companies go to considerable trouble to keep them secret. They are empirical and

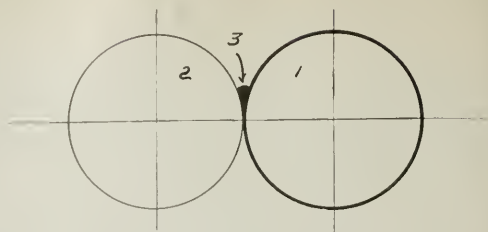


FIG. 3—OPERATION OF MIXING ROLLS

have been worked out by experiment. However, it can be said that with certain few exceptions most articles can be analyzed and the compound deduced by an experienced rubber chemist.

The correct proportions of rubber, sulphur and fillers are weighed out in the compound room. The batches are customarily of 100 lb. each. They are made up in galvanized iron pans and sent to the mixing room. It is hardly necessary to state that all mineral fillers must be ground very fine.

Mixing

In general the construction of the mixing rolls is similar to those used in washing, except that the surfaces are not corrugated. Fig. 2 is a photograph of a small set of mixing rolls. The usual factory size is from 35 to 45 in. in length, and 12 to 16 in. in diameter. The gearing is differential, the front roll running at 18 to 20 r.p.m., and the back at 20 to 25. During the operation the front one is kept slightly hotter than the back. This in conjunction with the slower speed keeps the plastic mass on the front roll. Both rolls are fitted with means of steam heating and water cooling, which are used when necessary. Set screws which operate on the front roll are used to give the desired distance between the rolls.

The first operation in mixing is to properly "break down" the rubber. The rolls are heated to a moderate temperature and the rubber passed through a number of times, until it becomes smooth and plastic but not sticky. It then covers the forward roll as is shown by 1, Fig. 3. When this condition is reached, the rolls are brought closer together, thus forming what is called the "bank." This is designated by 3 in the above-men-

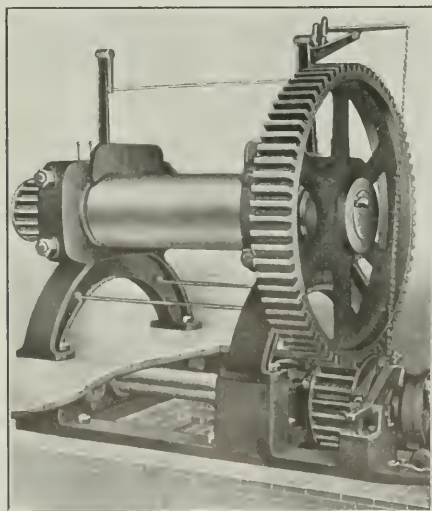


FIG. 2—SMALL-SIZE MIXING ROLLS

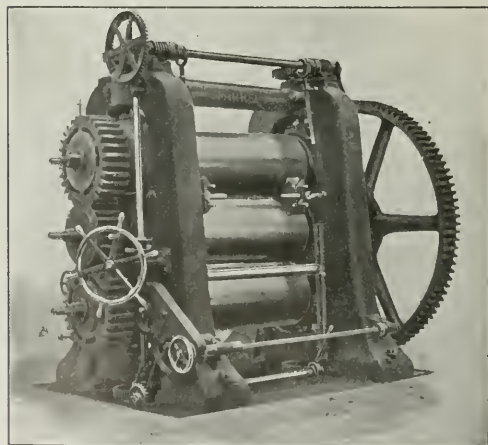


FIG. 4—24-IN. THREE-ROLL CALENDER

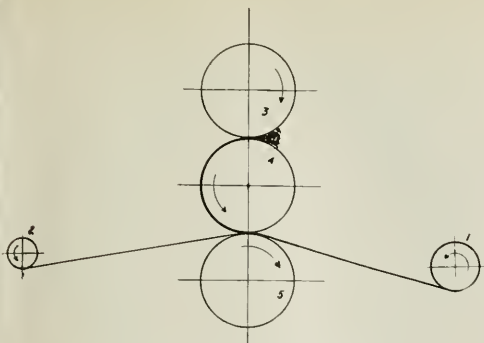


FIG. 5—OPERATION OF CALENDER

tioned diagram. Since the rubber heats up spontaneously on breaking down, it may be necessary to cool the rolls.

Shoddy is frequently broken down on separate rolls and added at this point, or the rubber and shoddy may be broken down together. Any oils or sticky material are usually added at this point. The attendant, aided by a short knife, cuts off pieces of the batch and throws these over and over on the rolls until a homogeneous mixture is effected. He then adds the powders as the mineral fillers are called. The bank acts like a third roll rotating in the opposite direction. It aids considerably in securing a good mixture.

The cutting and throwing process is repeated and finally the stock is removed, left to cool down slightly and passed through the mills, which have been opened a trifle so as to insure an even mixture. Following this the stock is sheeted for convenience.

The aim of the mixer is to have his batch well mixed before adding the mineral fillers, and to proceed as rapidly as possible from this point to avoid any overworking of the rubber lest it lose considerably in nerve.

Mixing machines are sometimes used. They consist essentially of inclosed rotating arms. The rubber is first broken down alone and the powders added. The operation is almost entirely automatic. Mixing machines find favor where considerable quantities of fine light material have to be handled. However, many old rubber men do not favor these machines, and claim that stock so mixed is apt to be deficient in nerve due to overworking or else poorly mixed.

Calendering

The object of the calender is to change the dough, or stock, as it is called, in the mixing room into sheets of even thickness, since it is from these sheets that most all rubber articles are made. Fig. 4 shows a "three-roll calender." The rolls are massive, correctly turned, and fitted with means for heating or cooling. Screws are provided for adjusting the distance between the rolls. Calenders are usually directly connected to a motor. Herringbone gears find the greatest favor, since they insure a more uniform speed. Altogether the calender is an expensive machine, and should be kept in use most of the time.

Fig. 5 illustrates the operation of the calender. The stock after being properly warmed up on a warming mill is fed in between rolls 3 and 4. By proper regulation of temperature it is caused to adhere to the middle roll, leaving the top and bottom ones clean. A strip of cloth called "liner" is taken from reel 2 and passes between the middle and lower rolls to reel 1. The sheeted rubber as it passes between these rolls is re-

ceived by the liner, which carries it to reel 1 where they are wrapped up together, the liner preventing the layers of rubber from adhering. By means of knives pressed against the middle roll, the sheet may be cut into strips of any desired width.

Frictioning

Frictioning, which consists of impregnating duck or other cloth with rubber compound, is also done on the calender. The only difference is that the rolls now travel at different speeds, the bottom one revolving at about two-thirds that of the middle roll, thus causing a wiping action. The duck is first well dried by passing it over steam-heated pipes in a duck drier. It passes through the calender from reel 2 to reel 1, as described under calendering sheets. The soft dough is forced into the pores of the duck first from one side, then from another. When it is desired to give a skim coat the rolls are opened a trifle and the friction passed through just the same as in sheeting. This places a thin layer of rubber on the friction on only one side.

Rubber Cement

The making of cement is rather an important branch of the rubber industry, as will later be appreciated.

Cements are made for all sorts of purposes. Those intended for cold vulcanization contain, of course, no sulphur. For patching a very good cold curing cement is made by swelling Para rubber in a suitable solvent. However, it is customary for cements to be made from compounded stocks, the purpose deciding the character of the compound. The chief solvents are benzole (90 per cent), gasoline (70-76 deg. B.) and carbon tetrachloride. The best results are given with benzole.

The stock or rubber from which the cement is to be made is first thoroughly milled. It is then sheeted and cut into fairly small pieces. These are placed in a churn with the required amount of solvent. After some time the rubber swells and forms a typical colloidal solution.

The grade of cement depends upon: First, the quality of rubber used. The addition of Pontinac or other highly resinous rubbers gives a thick, viscous cement of little holding power. Second, the kind and amount of solvent used. And third, upon the amount of mineral filler present in the stock.

Vulcanization

Vulcanization is effected by two principal methods. The first, hot process, is by heating rubber with sulphur. And the second, cold process, consists of treating it with a dilute solution of sulphur chloride.

Hot Process

This is effected in three principal ways. The first, heater cure, subjects the article to the action of live steam under pressure. The second, press cure, subjects

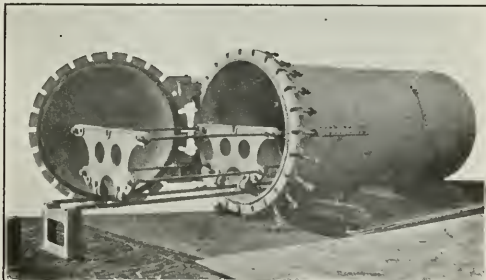


FIG. 6—DIRECT STEAM OR OPEN HEATER

it to hydraulic pressure and heats it indirectly by the steam-heated faces of the press. The third method, called the autoclave press, is a combination of the first two. The important factors in hot-process work are time and temperature. The latter is expressed in pounds per square inch steam pressure. Factory cures read so many minutes at so many pounds of steam, as 30 at 30 for example.

Live Steam Cure

Fig. 6 shows a direct steam or open heater. It consists of an autoclave equipped with a pressure gage, thermometer and self-regulating valve. An article to be cured by this method must first be wrapped tightly with a wet cloth. This is narrow and resembles both in appearance and application a bandage. Schidrowitz claims that where possible the live steam cure is best, since the steam seems to act as an accelerator. This method can not be applied to articles containing much oil substitute, owing to the saponifying action of steam at high temperature. Care must be taken not to release the pressure on the autoclave too rapidly lest the article become porous. The loss in time and heat occasioned by blowing off is quite considerable.

Press Curing

Fig. 7 shows a small multiple press. The heads A, B and C are heated by live steam under pressure. C is directly connected to the piston of the hydraulic press. In regard to this method, Schidrowitz makes the statement that in general, with given heat conditions, the better result is obtained by higher hydraulic pressure. The even distribution of pressure permits the production of relatively large articles where homogeneity is desired. Another advantage of the press is that the steam and hydraulic pressure can be regulated separately. Its great advantage is the difficulty in controlling the temperature of the heads due to condensation. If one face is hotter than the other the surfaces will not receive the same degree of vulcanization.

Autoclave Press

As stated previously, this method is a combination of the two above described. Articles to be cured are

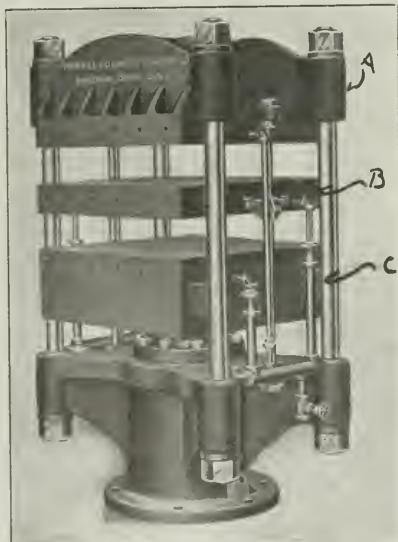


FIG. 7—SMALL MULTIPLE PRESS

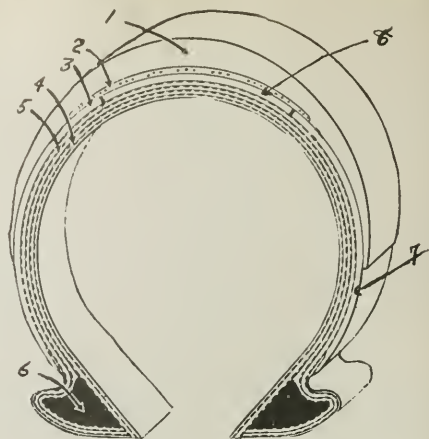


FIG. 8—SECTION OF AN AUTO TIRE

subjected to hydraulic pressure while contained in an autoclave. For example, auto tires which are cured in this manner, are built up on forms, clamped in molds and laid flat in the autoclave, the floor of which forms the head of the press. The molds are subjected to pressure between the top of the autoclave and this piston head. Steam is turned on just as in live-steam curing. For auto tires the hydraulic pressure amounts to around 1000 lb. per square inch.

Cold Vulcanization

In this process, rubber is vulcanized by the action of sulphur chloride, S_2Cl_2 . A 2 to 3 per cent solution in carbon bisulphide, CS_2 , or in carbon tetrachloride, CCl_4 , is used. Articles over 4 mm. thick cannot be cured in this manner since by the time the interior was vulcanized the surface would be over-cured and brittle.

The Manufacture of Tires

This subject is so broad that a complete discussion is entirely beyond this article. Ten years ago, when the tire industry began, they were made complete, that is, without a separate tube and casing as is the practice at present. This method was very expensive and tires were hard to make and hard to repair.

If the reader will refer to Fig. 8 we will take up the construction of an auto-tire casing, and consider the various parts and the necessary properties of each.

The principal parts are: Fabric, cushion gum, side strip, breaker strip, bead and tread.

Fabric.—Duck is fricated as previously described. It is commonly cut on the bias, and the tire roughed out on a form. This is made of heavy cast iron, since it is not removed until the tire is cured, and must therefore stand the high pressure of the press. Numbers 4

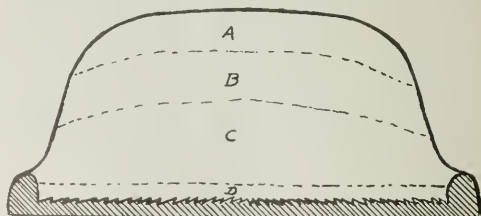


FIG. 9—SECTION OF TRUCK TIRE

and 5 show the layers of fabric. In good casings the fabric is made from long fibered or Sea Island cotton. The friction stock is very good, containing considerable rubber, no shoddy and as a rule no sticky materials. Much depends on the fabric, for it is the backbone of the tire.

Cushion Gum.—The gum cushion is indicated by 8. Its purpose is to add resiliency to the casing. It is a narrow strip of very good rubber, and as is shown, goes around directly beneath the point where the tread and the road surface make contact. It ordinarily contains around 80 per cent rubber.

Side Strip.—The side strip, 3 and 7, covers the sides and extends up under the tread to the gum cushion. It is not necessary to use such good material at this point. We usually find about 50 per cent rubber.

Breaker Strip.—This, 2, is a loosely woven piece of very strong cloth. It is placed over the gum cushion and covers the ends of the two pieces of side strip, thus tying them together. This is its purpose.

Bead.—The bead, 6, consists of a ring of hard rubber either with or without reinforcement by steel cable. Its shape depends on whether straight side or clincher rims are to be used. It is made up separately and applied between the layers of fabric.

Tread.—The tread, 1, is the most important part of the casing. It must be tough and hard but not brittle. Being in contact with the road surface, its wearing power decides the life of the tire. Because of the high degree of toughness necessary, one will usually find in it considerable quantities of zinc oxide. Ordinarily around 50 per cent is used to about 40 per cent rubber. The remainder is sulphur and miscellaneous filler.

The procedure of building up a tire casing is then as follows:

The operator begins with the fabric. The bead is placed in position between the layers. Next the gum cushion is applied. The side strips cover the sides and are bound together by the breaker strip. The tread goes on last. It must not be taken that any large sections are put on at once. Each separate part, except, of course, the breaker strip, is made up of a number of thin layers.

A tire casing so prepared is taken to the curing room, clamped in a mold and placed in an autoclave press for vulcanization. The period ranges from one to two hours at 45 to 55 lb. of steam. Where non-skid tires are being made the mold has depressions corresponding to the studs desired. The hydraulic pressure forces the tread into these, so that when the mold is removed the studs stand in relief. After trimming and wrapping the tire is ready for shipment.

Inner Tubes

A casing so prepared requires a strong elastic and air-tight inner tube. For this purpose a stock containing around 80 per cent rubber is used. The filler may be antimony golden sulphide, if non-blooming tubes are desired, or it may be simply zinc and iron oxides. Gray tubes have varying composition, depending on the maker's experience. The stock is sheeted very thin and the tube built up lengthwise on a mandrel by rolling. It is wrapped with cloth and cured in live steam. After splicing the valve is set in place and it is ready for use.

Solid Tires

Fig. 9 illustrates a section of a truck tire. These are usually built up on a ridged steel rim. D indicates the hard base, which is very nearly ebomite. Its purpose is to bind the tire to the rim. C is the elastic part and serves the same purpose as the air of a pneumatic tire. B is the next layer and is slightly tougher

than C. A is the tread and must be very strong and tough. It usually contains 40 to 50 per cent rubber, 2 to 4 per cent sulphur and the rest mineral filler.

Solid tires are also cured in an autoclave press.

Belting

Duck for belting is dried and frictioned as has been described. It is cut lengthwise into strips whose width depends, first on the size of the belt, and second upon the method of manufacture. One manner much used is to form the inner plies of strips having the same width as the belt. These are stacked and placed in the middle of a strip of double the width. They are next drawn through an opening having flared edges which fold the bottom strip over the top and form a butt joint. The belt is then passed between rolls which press the plies firmly together. At the same time the joint is covered by a narrow strip of rubber. While some of the most expensive belts are made without covers, it is usually the practice to have them. In fact, on some grades of conveyor belts even a gum filler is placed in the center of the belt. When the belt is to have a cover, this is commonly calendered on to the outside ply of duck before application to the belt.

Another method which is said to give a stronger belt is to cut each strip of duck twice as wide as the belt. The first strip is folded on itself, so as to form a butt joint. This strip is placed on the next with its joint down. The process is repeated until the belt has the desired thickness. The top joint is covered with a narrow strip of rubber or a cover placed on the belt.

The belt is cured in two steps. First it is tightly coiled and wrapped so that only the edges are exposed. It is then placed in a large heater where it is subjected to the action of live steam. When the edges are cured it is finally vulcanized in a long press. It is tightly stretched and cured in sections of from 10 to 30 ft. in length.

With conveyor belts the cover is always made of good material, but for transmission it is customary to use cheap covers and put the most expense into the friction, so that the plies of duck will be firmly held together.

Balata Belts

A discussion of rubber belting would not be complete without mention of balata. This substance, while having the same chemical formula ($C_{10}H_{12}$)_n as rubber, has almost no elasticity. Its behavior with heat is also quite different. At slightly over 70 deg. C. it softens, and by heating it a little higher duck may be impregnated with it. A balata belt is built up just as previously described under rubber belting, using, however, sheets of this treated duck. Successful operation depends considerably on keeping the balata at the proper temperature for working. When the desired thickness of belt is reached it is subjected to hydraulic pressure in a moderately heated press, thus forcing the balata substance well into the pores of the fabric. When it cools the balata sets and the plies are firmly bound together.

Balata belts are, as a rule, very good. The use for which they are best fitted is that of running under damp conditions.

Hose

This forms one of the most important branches of the rubber industry. Like the manufacture of tires, this subject is also so broad that we are unable to go deeply into it. The subject may be sub-divided as follows: Cotton jacketed, braided, and wrapped.

Cotton Jacketed.—This includes the various grades of fire hose, and is made up of a rubber tube with either a single or double cotton jacket. The tube is made from a calendered sheet, cut wide enough to give the proper



FIG. 10—52-FT. COMBINATION HOSE-MAKING AND WRAPPING MACHINE

circumference and a small lap. This lap is cemented and the tube given a semi-cure. This fixes the cement and also gives the tube enough strength for subsequent operations. The cover is woven separately. It is placed on a long table and a rod passed through it. This carries a cord, to which is attached the tube. The workman pulls the tube first through cement and then through the cover. The coat of cement is called the backing. Then he fills the hose with steam under pressure, which expands it, thus forcing the cement well into the cover and at the same time vulcanizing the rubber.

Braided Hose.—This variety is of practically recent introduction, but is growing in popularity and seems to be very good. Garden hose is one example of this class. The tube is run on a tube machine. For this purpose a soft stock is necessary. It is warmed to a sufficiently high temperature on the rolls to make it plastic, and in this condition it is forced through a die which may be adjusted to give any desired thickness of wall. A worm similar to that used on a sausage machine carries the stock forward and forces it through the die. In this manner hose of any length can be made. For this reason it is sometimes called continuous hose. Cheap gas tubing, and, in fact, most all small size single wall hose, is made in this manner.

Having formed the tube on the tube machine, it is then led through a braiding machine, where fabric is braided around it. The tube may or may not have been coated with cement, depending upon the kind of stock used and also on the purpose of the hose. The operation may be repeated as often as desired. When the required number of plies is produced the hose is sent through another tube machine, where the cover is placed on it in much the same manner as the tube was formed.

Vulcanization is effected in a press. During the operation air pressure is maintained inside the hose, which forces the rubber well into the meshes of the loosely woven braided fabric.

Wrapped Hose.—In this class I will include all those varieties of hose made up of a tube, cover, and friction. The friction is simply duck, coated as previously described under frictioning. Under this head come many varieties of hand-made, machine-made, and semi-machine-made hose.

All varieties are, however, built up on a mandrel. The tubes used may be made from sheets as described under cotton hose, or may be run on a tube machine. In this case they are placed on the mandrel by the aid of compressed air.

Short length varieties, such as air-brake and tank hose, are mostly machine made. This machine is not very complicated and consists principally of three rollers, two on the same plane and the other immediately above and half-way between the other two. The mandrel with the tube is placed on the rolls, the correctly cut strip of friction applied, the top roll let down and

the machine started. The tube is quickly wrapped. The cover is put on in the same manner. Armored hose is made by placing a spiral of wire between the plies as desired.

Long length hose is made in just the same way, except that here the machine is much longer. The length is usually 52 ft. and the hose is made in 50-ft. lengths. Fig. 10 is a photograph of such a machine. Hose made in this manner is wrapped with cloth and cured in live steam.

Molded Goods

This group includes valves, gaskets, and thousands of cheap articles. These are built up on a mold and cured in a press. Because of the low price at which they are sold, much attention is given to efficiency and speed of operation.

Dipped Goods

Under this head come rubber gloves, some surgical goods, and other thin rubber articles. They are built up on a form. A single carrier holds often as high as 100 of these. After dusting them with soapstone they are dipped in rubber cement. After drying the process is repeated until the desired thickness is produced.

Such articles are cured while on the forms by dipping in a solution of sulphur chloride; that is, by cold vulcanization. After curing, they are well washed, first with water, then with sodium carbonate solution, and finally with water. After drying they are peeled off the form, dusted with soapstone, and are then ready for shipment.

Spreading

Under this head comes the manufacture of proofed textiles. The process consists of spreading a very thin layer of rubber evenly over the fabric.

The spreading machine is a long, steam-heated iron table, provided with rollers at either end. The cloth as it is unwound from one roll passes under an iron "doctor," where it receives a certain quantity of cement. It then travels over the surface of the table, where the solvent is evaporated. The process is repeated until the desired thickness of coat is obtained.

Since considerable solvent is used in spreading, the tables are covered by hoods which lead to a refrigerating system, where most of it is recovered.

Such material is cold cured by passing it through sulphur chloride solution. The product is well washed and dried.

Shoddy

At various places in this article mention has been made of shoddy or reclaimed rubber. This branch of the industry is very large and the material finds application to a more or less extent in all branches of rubber practice except tire making. It has been said that two-thirds as much rubber scrap comes back to the factories as the crude rubber which they receive. How many times rubber is used over and over again is not known.

but it is undoubtedly a large number, and forms a good illustration of the reincarnation theory. However, as it is successively used it descends in the scale of value. Tire scrap furnishes the best grade, since it is made from the best of rubber and seldom contains any shoddy. This goes into other materials, such as steam hose, which in time wears out and comes back to be made into still a lower grade.

A true reclaiming process would give back the rubber in its original condition, minus the sulphur which was chemically added on during vulcanization. So far no such process has been brought forth. What is done is merely the freeing of the rubber from the fabric and depolymerizing it so that additional sulphur may be added and the material revulcanized. The alkali and acid processes are the most important.

Alkali Process.—The rubber scrap is finely ground between rapidly rotating knives. This material is placed in long cylindrical drums fitted with paddles. Here it is heated for around twelve hours with a 10 to 20 per cent solution of caustic soda. This treatment removes all saponifiable organic fillers, such as vegetable oils and substitute, and also the free sulphur. The fabric is destroyed and rendered soluble. The particles of rubber are secured by screening the tank liquor. They are well washed on a washing mill. After working a little they stick together and may be sheeted. The sheet is dried either by vacuum or by working on a hot mill. If the scrap used was rather low grade, it may be necessary to add tar, heavy oil, or other material to give it cohesiveness.

Acid Process.—This process is the same as the alkali, except that a dilute solution of sulphuric acid is employed instead of caustic soda. The product is not considered equal to that of the alkali process, and oil must be added to give it the desired degree of cohesiveness.

CONCLUSION

In this and the previous article I have endeavored to outline briefly the most salient points in respect to this industry. Rubber is a close competitor with steel in the number of things which may be made from it. It surpasses steel in the range of properties obtainable. The industry is of great importance, and the future will doubtless call upon it more and more.

The Mechanical Principles of the Blast Furnace—II

BY J. E. JOHNSON, JR.

The Support of the Charge Column

The support of the charge column is made up of at least four elements. First, the upward pressure of the gas. Second, the friction of the charge on the sides of the shaft. Third, the vertical upward thrust against the charge from the downwardly converging slope of the bosh walls. Fourth, flotation in the molten mass of iron and cinder in the hearth. To these we might almost add a fifth, the dragging of the pasty zone against the walls at the top of the bosh, but this may be counted as a part of the friction, especially as we have no means of measuring either.

The weight of the charge column is very generally over-estimated by those who have not made calculations upon it. It is ordinarily assumed that this weight is 50 or 100 lb. per square inch, but obviously this is not true. If we estimate that three-fifths of the charge by volume is coke with a specific gravity of 0.45, and two-fifths ore and stone with a specific gravity of 2.5, we shall have a column 1.18 times the specific gravity of water. Taking the height from the tuyeres to the

stock line of a modern furnace as 70 ft., the water pressure corresponding to this height is 30 lb., which would correspond to a weight of charge column of 35 lb., if the materials descended to the hearth in the condition in which they are charged. But as a matter of fact the ore loses about 25 per cent of its weight in the form of oxygen carried off by the ascending gases, while the limestone loses 40 to 45 per cent of its weight through decarbonization. Moreover, in many cases the bulk of the ore is vastly increased by the great volume of extremely light, flocculent carbon deposited upon it by the action of the gas. As a net result the weight of the charge column is greatly diminished, while considering only that part of it down to the base of the shaft, its diameter and area are greatly increased by the outward batter of the furnace still further reducing its weight per square inch.

In my paper "Notes on the Physical Action of the Blast Furnace" before referred to in this serial, I have embodied some calculations on this subject which are probably just as applicable to present conditions as they were to the conditions on which they are based, and are therefore quoted.

In order to have a concrete example on which to base calculations, let us take, as representative of present conditions, the Isabella furnace, of which the more important data are given in Mr. Gayley's paper on the dry blast. The lines of this furnace are shown in that paper.

Let us assume, for an average of summer and winter conditions, that the output is 400 tons per day and the burden per 10,000 lb. of coke is 22,000 lb. of ore and 5500 lb. of limestone; the coke per ton of iron is 1900 lb. and the ore per cent through the furnace, to agree with the above assumption, 53.6 per cent.

The total content of 18,090 cu. ft. are divided as follows: 1193 cu. ft. in the hearth, 3087 in the bosh, and 13,810 in the shaft above the bosh.

Assume that coke weighs 28 lb., ore 135 lb., and limestone 90 lb. per cubic foot—figures sufficiently exact for our purpose, then the volume of a charge will be 357 cu. ft. of coke, 163 of ore, and 61 of stone, or 581 cu. ft. in all. Each charge weighs (as charged) 37,500 lb.; hence the initial average weight per cubic foot is 64.5 lb.

The weight of stock in the shaft of the furnace can easily be calculated from the weight and volume of the charge given above, but the result so obtained is entirely too high for several reasons. In the first place, the ore swells enormously in volume under the action of the gas and the deposition of carbon. Secondly, the oxygen of the ore is nearly all removed, lightening it about 30 per cent. Thirdly, all the CO₂ of the limestone is driven off, lightening it 44 per cent.

It is impossible to express the sum of all these effects with quantitative accuracy, but if we assume that the ore doubles in volume, and that the limestone decreases 44 per cent in weight by the time the charge has reached the top of the bosh, and neglect all the other conditions, we shall certainly be on the safe side in estimating the total lightening effect.

This gives a final reduced weight of 47.2 lb. per cubic foot, and if we assume the change to have occurred uniformly as the charge descended, we can calculate the weight of stock in the shaft, which will be, on this basis, 755,000 lb.

The difference of pressure between the tuyere-zone and the stock-line is 14 lb., and this is evidently all used up in forcing the gas formed at the tuyeres through the column of stock.

In the absence of knowledge as to the rate at which the pressure falls, we may reasonably assume that it is proportional to the distance traversed. This gives a

loss of 2.6 lb. to the top of the bosh, leaving a pressure at that level of 11.4 lb. more than at the stock-line. Leaving out of account what goes on below that level, it may be observed that, since the stock exerts a resistance of this amount to the passage of the gas, the gas must also exert a resistance of an equal amount to the passage (descent) of the stock, since action and reaction are always equal and in opposite directions. In this resistance to the descent of the stock will be found the cause of slips.

The pressure of 11.4 lb. on an area of 21 ft. diameter gives a total pressure of 568,000 lb.; but the difference of pressure is all that counts, and each zone is a little larger than the one above, so that the whole difference of pressure only acts on a central area equal to that of the stock-line. A deduction of 184,000 lb. must therefore be made from this 568,000 lb., and the net resistance offered to the descent of the stock by the blast is thus 384,000 lb., which is more than half of the entire weight of the column of stock. From the unbalanced remainder must be deducted the weight necessary to overcome the friction of the stock on the walls, which it is not practicable to estimate in figures. Probably it is not less than from 10 to 20 per cent of the weight of the column, and may easily be more. Assuming it to be 15 per cent, it amounts to 113,000 lb., which added to 384,000 gives 497,000, or about two-thirds of the total weight of the stock-column.

Under normal circumstances the remaining third of that weight is enough to bring the column of stock down; but if any local derangement takes place, and the pressure ceases to fall at a regular rate, we have a condition the trouble-producing power of which is cumulative, for owing to the increased resistance, the flow past the obstructed point is reduced, and with it the friction and counter-pressure below, while owing to the damming action of the obstruction, as the engine continues to blow the same quantity of blast, the pressure soon runs up, and as the velocity is reduced the high pressure that normally exists only in the lower part of the furnace extends up under the obstruction. This compresses the obstruction more, and forces it more tightly against the furnace walls, while at the same time, by reason of the greater pressure, it becomes denser, and offers still greater resistance to the passage of the gas, which in turn augments all the other effects, until the furnace is "stuck" tight. The "plug" is in a conical passage and cannot yield backwards, and things remain in this condition while the stock below continues to settle until a cavity is formed underneath the "plug." Finally, through some accidental weakness in the obstruction, or through the slacking of the blast and reduction of the pressure under it, which allows the plug to come loose, the condition is broken, and the suspended mass falls.

As to the cause of the violent ejections of stock, some of which take the bell along, there has been much speculation, and various explanations have been made, none of which have seemed adequate. The true explanation seems to be that the whole furnace below the plug is a reservoir of compressed gas (this being especially true of the cavity formed under the obstruction), and when this latter gives way it is like knocking out the keystone of an inverted arch under pressure—the instant the arch is broken the compressed gas has ample energy to carry away, in its sudden escape, part of the overlying stock.

The greater the cavity the longer the "blow"; while the further down in the furnace the obstruction lies the higher the pressure under it is likely to be, and the greater is likely to be the mass of material above it through which the gas must make its exit and portions of which it will carry along.

To the initial increase in resistance to the passage

of the gas several causes may contribute; but, if the furnace is not scaffolded, the most important one is the deposition of carbon-dust through the splitting up of the CO into CO₂ and C. Both the extent of this action and the time of its beginning vary greatly with the character of the ore through which the gas passes, as has been shown in various papers read before the Institute and elsewhere. It has also been shown that the action proceeds with great rapidity when it has once begun, thus localizing it in some cases to a certain restricted zone in the furnace, both below and above which the charge is more open—below, by reason of its downward movement and the increased shaft-diameter reached thereby; above, because no carbon has yet been deposited in it. The slips thus tend to be localized in this zone; and hence most of the slips from a given furnace, which slips habitually, would have about the same degree of violence. Practice shows this to be the case.

The resistance of the gas column to the descent of the charge has been treated above as if it existed only above the top of the bosh, though as a matter of fact it exists all the way down to the tuyeres, but has not as great an effect in the bosh as it has above that region for the reason that in the latter region the area on which the smaller blast pressure acts is greater than that on which the larger pressure acts, that is to say, the pressure at the top of the bosh is smaller but the area of this zone is larger, while the hearth pressure is larger but its area is smaller. Therefore the difference in the products of these two is much less important than it is in the case of the bosh zone and the stock line where the greater pressure exists over the greater area and the smaller over the less.

In further explanation of the lifting action of the gas current on the charge column it may be remembered that one of the approved methods of lifting grain consists in delivering it into a vertical pipe up which a current of air is traveling at a high velocity. This is not in any way connected with lifting water by suction, through the removal of air, which is limited to 34 ft., but may be carried on practically without reference to the height. But when we find even approximately what the actual velocity of the gas current is, we realize that the present action is not altogether similar to this.

We have already seen that the velocity through the shaft is approximately constant so we can determine it roughly by reference to the hearth conditions only.

Assume a furnace of ordinary dimensions with a 16-ft. hearth blown with 45,000 cu. ft. of blast as measured by piston displacement or, say, 40,000 cu. ft. actual at atmospheric temperature and pressure compressed to 15 lb. pressure, and heated to 1200 deg. The absolute

volume becomes $40,000 \times \frac{1660}{530} \times \frac{15}{30} = 62,600$ cu. ft.

The area of the hearth empty is 200 sq. ft. but this is filled with coke, through whose voids only, the blast must pass. Assuming these conservatively as one-fourth of the total (see below) we have a net area certainly not to exceed 50 ft., through which all the blast must pass. This would give a velocity of $\frac{62,600}{50} = 1250$ ft.

per minute, but it must be remembered that this refers to the voids in the coke by itself and takes no account of their obstruction by molten iron and slag which as we shall later see is very great. If we assume that they amount to 50 per cent of the original area we shall probably be safe and this would double the velocity, making it 2500 ft. per minute or approximately 30 miles per hour and it may well be that this figure is too low rather than too high.

This velocity alone, however, is not sufficient to ac-

count for the drop in pressure in so short a distance but there is another factor of great importance; the roughness of the passage through which the gas column must pass, the "wetted surface" of the conduit (the stock column) is almost infinite and when we remember the vast effect of a slight increase in the roughness of any conduit on the friction of the fluid passing through it we have no difficulty in understanding the pressure drop even though the velocity be no more than 30 miles per hour, and, of course, the pressure drop is the direct measure of the lifting power of the charge rather than the velocity. In other words the action in this case is rather that of a leaky piston than the transportation of loose material by a rapid air current.

The Friction on the Walls

The effect of the friction on the walls is very great and must not be ignored though we have no means of estimating it accurately. It has been found in cylindrical grain bins that something like two-thirds of all the weight of the grain is taken on the side walls, but we cannot expect so large a percentage to be carried this way in the case of the blast furnace because the stock is kept in a more or less violent state of agitation by the current of gas rising through it. A strong upward current of gas produces a tremendous effect in the internal friction of a loose mass of solid matter particularly one containing much fine material, the agitation of the smaller particles makes them act almost like a liquid and exercise a corresponding influence on the larger particles. A mass of dry sand which might stand at a slope of 20 deg. when quiescent would not stand on one of 5 deg. if agitated by a current of air from below. On the other hand, the pressure of the charge column against the sides may be very much greater than what we should expect from its weight alone, that is to say, the pressure which the walls would receive if considered as a vertical retaining wall for an embankment. This is because of the tremendous swelling which frequently takes place in the ore due to carbon deposition.

These conditions make it exceedingly difficult to apply even our slight knowledge of the internal friction of such materials as compose the furnace charge to determining the effect of wall friction quantitatively, but we do know that the charge sometimes hangs in the furnace at a height far above the beginning of the pasty zone and sometimes remains hanging even when the blast is taken entirely off. This can only be due to wall friction and indicates that this may sometimes exceed 100 per cent though undoubtedly its normal amount is very much smaller.

THE SUPPORT DUE TO THE UPWARD COMPONENT OF THE REACTION OF THE BOSH WALLS

Obviously if the bosh walls were continued down until they met in a point the inverted cone so formed would support the stock column completely, and the portion of this cone which actually exists furnishes its portion of support, this, of course, ignores all questions of flotation from the liquid in the hearth which we may exclude for the present. Thinking only of the steep slope of the bosh and of what a small frustum of a complete cone it is, we might be inclined to dismiss as insignificant the amount of this support especially in view of the modern tendency to build furnaces with large hearths and extremely steep, short, bosh slopes. But even in the most extreme of these furnaces this would not be correct, for the amount of this support is obviously proportional, other things being equal, to the difference in the area of the zones projected into a horizontal plane. Even with a 22-ft. bosh and 17-ft. hearth this difference is 40 per cent of the bosh area and it

seems reasonable to assume that 40 per cent of whatever unbalanced pressure may exist down to the tuyere zone is taken by the bosh slope even in this case. Incidentally this indicates that a change in hearth diameter of 1 or 2 ft. may have a considerably greater effect in the mechanical operation of the furnace than we might at first glance suspect. That this is true we have an abundance of experimental evidence.

In considering the shape of the furnace we shall presently note that as blast pressures have risen supplying more support for the charge column, hearth diameters have increased leaving the bosh area smaller and so supplying less support. This at least suggests that the proper descent of the charge column only takes place when the sum of the resistances thereto does not exceed a certain total.

The Flotation of the Charge Column in the Liquid

This is an exceedingly complicated question. It is rather illuminating to consider the volume of molten material in the hearth at its maximum. Let us assume that a 500-ton furnace casts four times per day and that one-fourth of the total cinder, or 300 lb. per ton, is in the furnace before cast, and that the hearth is 16 ft. in diameter which gives an area of 200 sq. ft., all about in accordance with modern practice.

We may assume that the volume of iron at the high temperature at which it exists in the furnace is 5 cu. ft. to the gross ton, and that molten slag weighs 150 lb. to the cubic foot, so that 300 lb. of slag have a volume of 2 cu. ft., which added to the 5 cu. ft. of molten iron makes a volume of 7 cu. ft. per ton. One hundred and twenty-five tons of iron would therefore correspond to a volume of liquid of 875 cu. ft., or sufficient to fill the hearth to the depth of a little less than 4½ ft., in other words not very much over half way up to the tuyeres.

On this basis we could dismiss the idea of flotation altogether if we considered the charge column to end at the tuyeres, but as a matter of fact we know that it does nothing of the kind, and that it must settle until it rests upon the hearth bottom, or until it is floated by the liquid in the hearth. Of course, if the stock column were only 8 or 10 ft. high it would readily be floated by the liquid, but when we consider the great height of superincumbent stock resting upon it, and forcing it down, we realize that it may be forced to the bottom of the bath at least in furnaces with a small blast pressure and shallow bath.

The result of forcing the stock column down into the bath is to raise the level of the liquid very greatly since the latter can occupy only the interstices in the coke. We do not know what these amount to exactly, but some careful experiments I made several years ago showed that the voids in thoroughly mixed crushed ore were about 33 per cent, while the percentage of voids existing between spheres closely packed is about 35 per cent of the volume of the spheres or about one-quarter of the volume of the space occupied. We may therefore assume without chance of great error that the percentage of voids in the coke as it exists in the hearth and bosh do not exceed 33 per cent of its net volume, or one-quarter of the total, which means that the height of the liquid must be four times as great as that estimated above or nearly 18 ft., which would bring the liquid well above the tuyeres if the coke column extended down to the bottom of the hearth. This is at least partly in accordance with the facts, since, of course, we know that the cinder will flow back into the tuyeres and rise in the penstocks to a considerable height if the blast be taken off before first "flushing" the cinder out of the furnace.

It is instructive to make an estimate of the floating

effect of the liquid bath even though we must use approximate figures.

Assume coke to weigh 28 lb. per cubic foot loose and to contain 25 per cent of voids, then its weight "solid" is 37 lb. per cubic foot. The weight of slag per cubic foot is as above given about 150 lb. and of iron 450 lb.; on the basis of the weights of these in the hearth and their combined depth of $17\frac{1}{2}$ ft. in the interstices of the coke, the depth of slag alone would be 5 ft. and that of the iron $12\frac{1}{2}$ ft. The buoyancy of the coke in slag per cubic foot of space is three-quarters of $(150 - 37)$ or about 85 lb. and for the whole depth of the slag it is 425 lb. per square foot upward thrust, for the iron it is three-quarters of $(450 - 40)$ or about 300 lb. per cubic foot and would be twelve and one-half times as much if the coke were submerged in the iron to the bottom of the hearth or 3750 lb. per square foot, this added to the 425 lb. per square foot due the submersion in the slag makes 4175 lb. per square foot or 29 lb. per square inch, which added to the 12 lb. due the blast pressure above the top of the bosh would make 41 lb. per square inch of total upward pressure on the base of the stock column or *considerably more than its total weight* without any allowance whatever for friction on the walls or support on the slope of the bosh. It is perfectly clear therefore that the weight of the stock column is not sufficient to force it to the bottom of the hearth when the latter contains much molten material but that it is submerged only to such a depth as supplies the upthrust not furnished by the other three forces. That the buoyancy of the base of the charge in the liquid in the hearth is a decided factor is proved by the fact that furnaces always settle very much more, immediately after cast than they do at any other time. Very frequently a furnace will settle perceptibly even as a result of flushing, and there is no reason to doubt that this is due to the removal of a portion of the buoying action of the liquid.

That the charge column does not rest on the bottom at least before cast time a very interesting proof has recently been given by Mr. F. L. Grammar.* If gaging prove that a furnace is settling regularly at the rate of 30 in. per half hour previous to cast and if during the half hour occupied by cast it settles 60 in., then obviously it could not have been resting on the bottom at the beginning of cast.

There is much reason to believe that the liquid slag not only stands in the furnace above the level of the tuyeres but that it is blown up through the interstices in the coke to a level many feet higher. The viscosity of the slag is considerable, and the blast has difficulty in making its way through it, as anyone will realize who has seen or even heard the slapping and blubbery which accompanies this action when it takes place under abnormal conditions when the slag is standing at a high level in the bosh and only a little blast passing through it (conditions which only exist with a badly deranged furnace) and we know that if the blast be taken off the furnace too quickly, even though the slag be below the level of the cinder notch when it comes to rest, we are more than likely to have the cinder come back in the tuyeres, which, of course, can only happen if at least a part of the slag has been well above their level.

In order to form a picture in more easily comprehensible terms I have sometimes thought that we might take a glass tube some 2 in. in diameter, and insert into it, 1 in. from the bottom, some $\frac{1}{4}$ -in. nozzles piped to a supply of air under slight pressure, fill the tube with water to a level half way up to the air nozzles, pour in sufficient granulated cork or other light substance to fill the tube for a height of 10 or 12 in., and then blow

air through the air nozzles in sufficient quantity to keep the water which is raised up around them by the descent of the cork, in a lively state of agitation. It is obvious that the cork would be supported partly by this flotation in the mass of bubbles into which the water would be converted, and partly by the ascent of the air through its interstices, and perhaps some of its weight would rest on the bottom of the tube.

Such a mental picture shows us how impossible it is to estimate exactly the value of each component in supporting the column of cork.

Limitations to the Size of the Furnace

The use of the formula for blast pressure as a tool of investigation enables us to discover the reason for certain facts of practice not otherwise easily understood. If furnaces be built larger they must obviously be blown with a proportionately increased quantity of wind if they are to yield results commensurate with their size, and in fact this is always expected of them. There are a few furnacemen who have built furnaces much larger than is customary for the tonnage which they desired to produce, but this practice is very rare though extremely sensible and advantageous. Generally considerations of corporation policy force the manager to produce an amount of iron approximately proportional to the volumetric contents of his furnace. Proceeding on the assumption that this condition must be met, we obtain the following results: W , the quantity of blast per minute, to be proportional to the capacity of the furnace, must vary as D^3H with the 22-ft. x 90-ft. furnace and 45,000 cu. ft. of wind $\frac{W}{D^3H} = 1.03$, and any other furnace with dimensions D_1 and H_1 must be blown with $1.03 D_1^3 H_1$ cu. ft. of wind to maintain this proportion. Then from the general formula we have

$$P_1^3 - P_2^3 = 0.0080 \frac{(1.03)^2 (D^3 H)^2 H}{D^3} = 0.00085 H^3.$$

For the 22-ft. x 90-ft. furnace the pressure figures out as follows:

$$P_1^3 = 216 + 0.0008 \times \frac{(45,000)^2 \times 90}{22^3} = 216 + 0.0008 \times \frac{2,025,000,000 \times 90}{234,000} = \frac{80 \times 202.5}{26} + 216 = 624 + 216 = 840 \therefore P_1 = 29 \text{ abs.} - 14.7 = 14.3 \text{ lb., which is just about the actual pressure for these conditions.}$$

For a furnace one-half larger and blown with proportionately more wind we should have then $P_1^3 = 216 + 624 \times (1.5)^3 = 216 + 2100 = 2316$ or $P_1 \text{ abs.} = 48.1$ or a gage pressure of 33.4 lb. That is to say, if the shape and relative dimensions remain the same, the difference of the squares of the absolute top and bottom pressures increases as the cube of the height. Therefore, if we build a furnace 50 per cent larger in all its dimensions than the present 90-ft. x 22-ft. furnace, and blow it with a proportionately increased volume of wind, we shall have a blast pressure of 33.4 lb. as against the normal pressure of the present size furnace of 14.3 lb., or nearly two and one-half times as much for an increase of 50 per cent in height.

The result of this is two-fold. First, we receive no return whatever for the power expended in compressing the blast. It is a necessary evil and nothing else. Therefore the power expended for this purpose is wasted from more useful purposes. Moreover the investment required to blow higher pressures increases all along the line, not quite in the same proportion, but still at a very rapid rate, and the interest and depreciation on this surplus investment is therefore an absolute loss. Second, the regular descent of the stock is made increasingly difficult and a point would soon be reached where it would become impossible.

*Private communication.

Referring to the detailed calculation of the Isabella furnace given above it will be seen that the pressure per square inch of the stock column, referred to the area of the top of the bosh, figures out to about 15 lb., or to put it a little more accurately that the blast pressure in this case is just about half of the total stock column pressure without undue allowance for expansion of the ore. A greater height from the top of the bosh to the stock line may reasonably be assumed to yield a proportionately increased pressure of the charge column. This in our assumed furnace 50 per cent larger in all dimensions than the modern 90-ft. x 22-ft. furnace would give a stock column pressure at the top of the bosh of about 22.5 lb., while the blast pressure at that point, on the basis of a uniform drop in pressure from top to bottom, would be one-fifth less than the tuyere pressure of 33.4 lb. or about 27 lb. In other words the gas pressure alone at this point would be materially more than the weight of the charge column, and the latter would therefore be unable by any possibility to descend regularly, since we have seen that there are three other important factors resisting it.

It is easy to see then that there are natural laws which prevent building furnaces of more than a certain height and corresponding diameter, and it is a matter of record that furnaces over 100 ft. high have been less successful than furnaces of about 90 ft. high, so that in one case furnaces 106 ft. high were cut down to 90 ft., and at another plant which started with furnaces 100 ft. high, the next ones, built after several years' experience were made 90 ft.

These facts taken in conjunction with the blast pressure and stock column figures given indicate that 90 ft. is about the limit of the size of furnaces which may be blown to full capacity. If larger furnaces were built it would be necessary to blow them with less than the proportionate amount of wind. This would probably be a wise move within moderate limits since the larger furnace blown with the same quantity of wind, of course, requires a smaller pressure and allows a longer time in preparation for the stock, while the initial cost is nothing like proportional to the increase in capacity, and the smaller pressure required means a smaller investment in power plant.

Against this on the other hand is the fact that the radiation from a given furnace is practically constant, and therefore the faster the furnace is driven the less the radiation loss per pound of iron. From the data given in the article on thermal principles we know that the radiation and cooling water losses are 10 or 12 per cent. This means that if we made only half as much iron in the same size furnace these losses would run up to about 20 or 25 per cent.

Looking again at the other side we have reason to believe that in present practice furnaces are often probably blown a little harder than the rate at which the coke consumption is a minimum. A little fuel is sacrificed for the sake of increasing the output since this keeps down capital and labor costs to some extent.

The Shape of the Furnace

This is a subject which should properly be treated under operation, but the considerations we have discussed may be expected to exert certain influences upon the shape of the furnace, and some of these we may now consider.

We may well ask ourselves why has the furnace the shape which a slow and painful evolution has given it in all parts of the world: a cylinder at the top and bottom, the latter surmounted by an inverted cone of quite rapid outward batter, and this in turn by a frustum of an upright cone of a much slower inward or convergent batter?

We have already seen that the shape of the furnace is approximately that which gives a uniform velocity of ascent to the gas column, its shape has been worked out upon purely empirical grounds, so that while this condition may be due to a coincidence it is more probably due to a relation of cause and effect entirely unknown during the development. There are certain other considerations of great importance and while we cannot attach quantitative values to them, and do not know all of their effects, we can point out some of their influences at least in a qualitative way.

The common base of the two conical portions of the furnace or the base of the short cylinder which connects them is universally known as the top of the bosh. What is this point?

It is in my judgment the zone in which the combustion of the oxygen of the blast to CO is complete, or viewing it from the opposite direction, it is the point at which the coke in its descent begins to be burnt by the blast. I have already discussed to some extent the fact that the lower part of this region is hotter than the upper, which at first sight it should not be if the combustion of the carbon to CO were going on uniformly throughout the zone, and I have given Professor Howe's explanation to me of this fact, that in the lower part of this region the coke was burned in the local and temporary excess of air partly to CO₂ with resulting high temperature, but that as this CO₂ rose through the excess of fuel in the bosh it was deprived of one atom of its oxygen by another atom of carbon, the whole forming CO instead of CO₂, and this reduction of CO₂ to CO is a distinctly cooling reaction. It is, therefore, to be expected that the upper portion of the bosh should be cooler than the lower portion, and this idea is not only not in conflict with, but is a confirmation of the conception that combustion of coke to CO is going on throughout the bosh, that being in fact the region of the furnace devoted to that purpose, in other words the combustion chamber. [Since the above was written I have been informed by John N. Reese of Youngstown of the results of some extensive investigations carried on by him, in which analyses of gas taken from the bosh at increasing heights showed contents of oxygen gradually diminishing and finally disappearing just about the top of the bosh. This is an independent experimental confirmation of the view here given far stronger than I had dared to hope for, and in my judgment forms convincing proof of its correctness.]

Above the top of the bosh we may assume that the material is in a "dry" condition. That is to say, neither the slag-forming materials nor the iron have begun to soften and become sticky. They then pass through a zone in which the sticky condition prevails, and finally as they become hotter and as the different slag-forming materials become more intimately mixed and therefore more fusible, both they and the iron pass out of the sticky condition into that of complete fusion with consequent liquidity and freedom of movement. It is obvious on a little consideration that this sticky zone is likely to obstruct both the passage of the gas upward and that of the stock downward, and in order that these shall not be prevented from moving in their appropriate directions it is obviously desirable that more room and slower velocity of travel should be provided at this point than at any other. This then should be the top of the bosh.

Granting that the top of the bosh is the point where the combustion of the blast to CO is complete and is also the point at which the solid materials enter the pasty state, this is obviously also the point where the gas generated in the hearth ceases to expand by combustion and drops below the critical temperature [since that is

by definition the free-running temperature of the slag]. From this zone upward it must contract by cooling through contact with the stock, and while, of course, it receives some increase in volume from the CO_2 of the limestone, this is much less than the contraction due to cooling.

From the top of the bosh downward the considerations which effect the shape are the decrease in the volume of the gas current as we approach the tuyeres (that is to say, its increase in volume as it rises from them), and the shrinkage, and eventual disappearance, of the coke.

We have then at the top of the bosh conditions which reverse within a short distance, first we have an increase in diameter necessitated both by the volume of the gas and the conditions of the stock column and then a decrease in diameter necessitated by opposite conditions, but it is evident that this reversal can not occur instantly and that instead of the two cones meeting at a fairly sharp angle, as it was once customary to have them do, there should be a transition zone either barrel-shaped as was once the custom, or a cylindrical section as is now the general practice.

Mr. Reese has recently pointed out to me that there is another reason for a cylindrical zone in this region which is that on some irons and some ores the furnace works on a very much more refractory slag than on others, and in consequence the pasty zone will be reached at a much higher level in one case than in the other and the maximum diameter at both heights can only be obtained by a cylindrical section.

To this Mr. Reese adds the valuable general law that the more infusible the slag the lower the bosh must be, which is borne out in a very broad way by all practice, both coke and charcoal.

Charcoal furnaces are ordinarily run with a very acid and fusible slag as compared with normal coke furnaces. Owing to its fusibility this slag melts at a higher relative elevation in the furnace than do ordinary coke slags. For this reason the top of the bosh of these furnaces should be higher relative to their height than that of coke furnaces. It has been found by experience that the height of the bosh of a charcoal furnace above the hearth level should probably never be less than 25 per cent of its total height and may be 28 or 30 per cent, whereas that of modern coke furnaces is considerably less than 25 per cent.

It is probable also that the cylindrical section in the pasty region has an advantage for another reason. The pasty zone must be penetrated by the charge column from above and by the gas from below, as long as this zone remains flat and horizontal, these actions can go forward without difficulty, but if the zone becomes arched either upward or downward due to greater or less activity in the center than at the side as is easily possible, then we have a condition of danger. For if the edges of the zone abut against a conical surface converging on the concave side of the curved pasty zone we shall have an arch formed which will tend to close up under the action of either the gas current or the stock column and obstruct the action of the furnace, perhaps even scaffolding it. But if the edges of the curved pasty zone abut against a cylindrical surface there is no "skewback" or support for such an arch and its chances of doing harm are much reduced.

CONDITIONS AFFECTING THE SIZE OF THE HEARTH

We can most conveniently consider the development of the size of the hearth from the chronological point of view.

In cold-blast charcoal furnaces, the earliest type developed, the hearths are extremely small, being only

2 ft. to 3 ft. in diameter for a corresponding bosh diameter of 8 ft. or 9 ft. In these furnaces the pressure of the blast is nearly always low so the shape of the gas column as affecting its resistance to the descent of the charge is less important than in furnaces with higher pressures. I am led to believe that this small hearth is necessary to obtain a sufficient concentration of heat to melt the iron and slag, for as shown by Fig. 1 on page 789 Vol. XIII (Nov. 1, 1915) these furnaces produce a very small amount of hearth heat per pound of fuel with their low critical temperature. Even with very high fuel consumption they are barely able to avoid freezing up, in other words their theoretical combustion temperature is but little above the free-running temperature of the iron and cinder.

In warm and hot-blast charcoal furnaces the theoretical combustion temperature is brought well above the melting temperature of the iron and slag, and the furnaces, therefore, are not forced to concentrate their heat in a very small space as is the cold-blast furnace. On the other hand, larger outputs are demanded of them, and this means a larger hearth in which to burn the fuel; it also means a greatly reduced upward batter of the bosh, and a much closer approximation of the hearth and bosh diameters to that required by a constant gas velocity.

In coke furnaces we go a step further in the same direction, hotter blast is used and more heat developed per pound of fuel. Therefore, we have a higher theoretical combustion temperature and less need for concentrating heat in the hearth, much larger outputs are demanded and consequently a larger hearth is necessary to burn the fuel, while, owing to the higher temperature of the blast entering the hearth, the ratio of increase in volume at the top of the bosh is smaller and the hearth can therefore be relatively larger. This is the general line along which furnace development has actually taken place.

The concentration of heat in the hearth is a factor often ignored in modern practice although so vital to success in the cold-blast charcoal furnace, but in spite of this neglect it is a factor which must receive consideration when foundry and high silicon irons are to be made. We desire a high temperature of the iron so that it may take up a high percentage of silicon, and we are not at liberty to obtain this high temperature by making a limey, and therefore relatively infusible slag, because the lime would resist the entrance of the silicon into the iron. Some other way must therefore be found of securing a concentration of heat in making such irons, and this is done by making the hearth of relatively small diameter which gives a corresponding concentration of heat in that region with a comparatively small and therefore hot and active column of gas rising from it, down through which the iron must pass and be correspondingly heated on its path into the hearth.

CONSIDERATIONS AFFECTING THE DIAMETER OF THE STOCK LINE

The considerations affecting the diameter of the stock line are first, the relative volume of the gas there as compared to that at the top of the bosh, on the constant velocity theory; second, the swelling of the charge due to chemical action as it descends; third, the necessity of providing sufficient disengaging surface for the gas so that its velocity may be kept down and the carrying over of an excessive amount of the fine portion of the charge prevented.

The small gas volume of cold-blast furnaces causes little or no trouble by carrying over fine ore and fuel from the top of the furnace, and therefore the latter can have a relatively small area and the shaft of the

furnace can be given a rather sharp outwardly descending batter, $1\frac{1}{2}$ in. to the foot, or even more.

The top diameter of warm and hot-blast charcoal furnaces is not increased as much proportionately as might be thought, for the smaller quantity of fuel used produces a proportionately smaller quantity of gas as compared with the total charge which it is required to heat up, the consequence is that most of the sensible heat is taken from the gas so that it is discharged from these furnaces quite cold, relatively speaking. I have seen top temperatures on a hot-blast charcoal furnace run for weeks below 212 deg. Fahr. The contraction of the gas due to this cooling offsets to a considerable extent the increased rate of blowing of such furnaces, and makes a relatively small stock line sufficient in this case also.

In coke furnaces using Mesaba ore the controlling factor in stock-line diameter is the velocity of the gas issuing from the surface of the charge. If this exceeds a certain rate fine particles of ore and other materials are picked up bodily and carried over with the gas current causing very serious inconvenience and loss in utilizing the gas and a loss of ore which is normally important and may easily become excessive.

If the output be great the gas volume must clearly be so likewise within narrow limits and the only way to reduce its velocity is to increase the area of the throat.

A. N. Diehl has stated that the surface of the charge in ordinary practice using a large percentage of Mesaba ore is constantly in agitation with particles rising and falling all over the surface and this is obviously the limit of gas velocity permissible.

The condition is precisely similar to that in a steam boiler where it has been found absolutely necessary to provide a given amount of disengaging surface for each cubic foot of steam produced under penalty of having the steam pick up and carry over such quantities of water as to make the operation of the boiler dangerous if not impossible.

This necessity of keeping within a certain limiting top velocity has exercised a potent influence on furnace lines, for the top diameter irrespective of all other conditions must be large enough to keep the issuing velocity below the danger line. I am inclined to believe that this consideration has forced the use of larger stock lines on hard-driven furnaces than other considerations demanded and that if we were satisfied to blow a little slower on a given furnace we could probably contract its stock line to the benefit of the operation as a whole.

In some ores the swelling action is slight and in others very great. In the experiments of O. O. Landig (*Trans. A. I. M. E.*, Vol. XXVI) some ores caused a deposition of carbon from CO five or six times the original volume of the ore, this being sort of a catalytic effect. The effect of such an increase in the volume of the ore tends to swell the whole charge and as it cannot secure more room above or below it must have room to expand laterally if it is not to become jammed in the furnace by this action. The furnace should therefore expand downward at quite a rapid rate to prevent the possibility of such jamming.

The diameter of the bosh being controlled by hearth and bosh conditions we are not at liberty to secure expansions by enlarging that and in consequence we have only one method of increasing this batter which is by carrying the stock line diameter of the furnace down as close as we dare to the point where the swelling of the charge begins or roughly to the bottom of the warming and drying zone, so concentrating the outward batter into a shorter zone and making it more rapid. This is the line along which the modern development of furnace lines has taken place. At the same time I have never

felt perfectly sure that it would not be safe to increase the bosh diameter and so secure greater batter. It is worth noting also that too large a stock line defeats its own end, as far as keeping down flue dust is concerned, for nothing makes so much flue dust as irregular descent of the charge, "slipping," and if the furnace works "tight" in the zone of carbon deposition this will result in top slips and the production of much flue dust, while if the stock line be somewhat reduced the resulting increase in outward batter supplies more room for expansion and relieves the "tight" zone, so tending to reduce slipping.

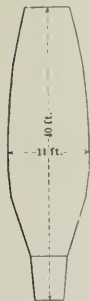
CONSIDERATIONS AFFECTING THE BOSH DIAMETER

We have already seen that the diameter of the gas column at the top of the bosh for constant velocity is larger than the actual bosh diameters in common use and have indicated certain conditions affecting this, but the conditions are too many and too complicated and we do not know positively enough about them to permit drawing very definite conclusions. We do know that in earlier days boshes were very much larger, particularly in relation to hearth diameter, than they are now (see Fig. 7 and following) and the rapid batter of the shaft and flat bosh slope which resulted being continued until they intersected, with no intervening cylindrical section made rather a sharp internal angle where they met and it seems to be abundantly established by the experience of the furnacemen of that day that this was a very inactive region. Its area was so great that the gas velocity through it was very low; accordingly it was a fruitful zone for the establishment of scaffolds which might content themselves with filling up the useless space, but once formed, were likely to grow too large and were certain to be irregular so that their influence on the work of the furnace was generally, though not invariably, bad. In my own experience I have seen a furnace whose bosh was too large for the work it was doing and whose work was less satisfactory than smaller furnaces had been.

On the other hand, many furnaces were built about thirty years ago with extremely small boshes, only one-fifth or less the height of the furnace in diameter, and some of these have been built in recent years, but except on very hard and irreducible ores which swell very little during reduction, they work with high pressure and consequent hanging and irregularity, therefore with high coke consumption, and in general very unsatisfactorily.

It would seem, therefore, that while the diameter for constant gas volume may not be and probably is not the correct diameter for the bosh, it is not very far from it and is certainly closer to it than some actual bosh diameters which have been used, both larger and smaller. It is evident from the discussion of hearth and stock line diameters above that both of these must exert an influence upon the bosh diameter in the directions and for the reasons pointed out. It seems certain, therefore, that the bosh diameter must be a compromise resulting from these considerations and many others, notable among these being the height and angle of the bosh; for given these and the diameter of the hearth the diameter of the bosh obviously becomes absolutely determined, as a consequence we cannot change one of these three alone but must change at least two and this fact greatly increases the difficulty of determining the controlling conditions.

In a general way the necessity of more room for expansion for the charge in its descent and for the gas volume in its ascent through the bosh would seem to indicate a somewhat larger bosh diameter than is now customary, as none of the influences mentioned indicate



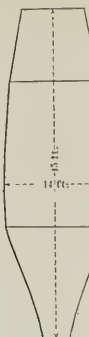
Blown-in, Mar. 15, 1844.
Blown-out, July 17, 1844.
Iron per week, tons, 52.30.
Average grade of iron, 1.58.
Fuel per ton pig, tons, 2.28.
Blast-temp., 500°-600°.
Blast-pressure, pounds, 4.
Number of tuyeres, 3.

FIG. 7—FURNACE NO. 1



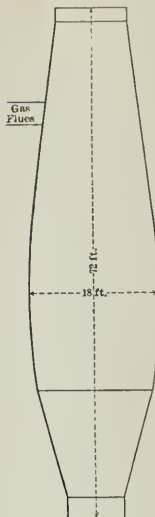
Blown-in, Sept. 5, 1843.
Blown-out, May 16, 1846.
Iron per week, tons, 57.46.
Average grade of iron, 1.89.
Fuel per ton pig, tons, 2.04.
Blast-temp., 500°-600°.
Blast-pressure, pounds, 4.
Number of tuyeres, 3.

FIG. 8—FURNACE NO. 1



Blown-in, May 25, 1845.
Blown-out, Aug. 21, 1847.
Iron per week, tons, 65.36.
Average grade of iron, 3.27.
Fuel per ton pig, tons, 1.95.
Blast-temp., 500°-600°.
Blast-pressure, pounds, 4.
Number of tuyeres, 4.

FIG. 9—FURNACE NO. 2



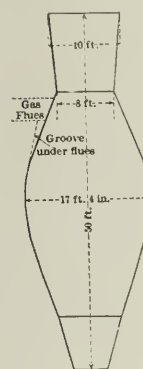
Blown-in, Jan. 7, 1869.
Blown-out, Feb. 28, 1871.
Iron per week, tons, 257.00.
Average grade of iron, 3.72.
Fuel per ton pig, tons, 1.35.
Blast-temp., 500°-650°.
Blast-pressure, pounds, 5.5-6.25.
Number of tuyeres, 7.

FIG. 16—FURNACE NO. 5



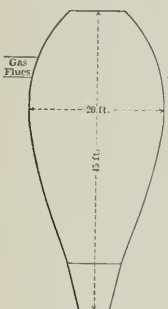
Blown-in, Nov., 1869.
Blown-out, Apr., 1873.
Iron per week, tons, 182.88.
Average grade of iron, 4.34.
Fuel per ton pig, tons, 1.59.
Blast-temp., 650°-750°.
Blast-pressure, pounds, 4.5-5.
Number of tuyeres, 4.

FIG. 17—FURNACE NO. 2

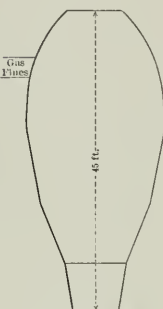


Blown-in, Aug. 22, 1869.
Blown-out, Feb. 6, 1871.
Iron per week, tons, 189.62.
Average grade of iron, 4.61.
Fuel per ton pig, tons, 1.48.
Blast-temp., 650°-750°.
Blast-pressure, pounds, 4.5-5.
Number of tuyeres, 5.

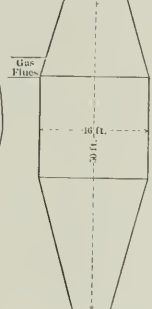
FIG. 18—FURNACE NO. 3



Blown-in, Mar. 2, 1851.
Blown-out, July 24, 1853.
Iron per week, tons, 114.04.
Average grade of iron, 3.42.
Fuel per ton pig, tons, 1.82.
Blast-temp., 500°-600°.
Blast-pressure, pounds, 4.
Number of tuyeres, 5.

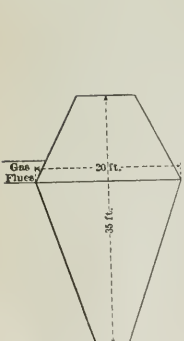


Blown-in, Sept. 20, 1853.
Blown-out, Mar. 28, 1855.
Iron per week, tons, 140.63.
Average grade of iron, 4.14.
Fuel per ton pig, tons, 2.03.
Blast-temp., 500°-600°.
Blast-pressure, pounds, 4.
Number of tuyeres, 5.

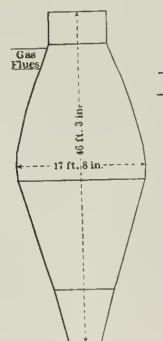


Blown-in, July 1, 1855.
Blown-out, July 1, 1857.
Iron per week, tons, 131.47.
Average grade of iron, 2.72.
Fuel per ton pig, tons, 1.91.
Blast-temp., 500°-600°.
Blast-pressure, pounds, 4.
Number of tuyeres, 5.

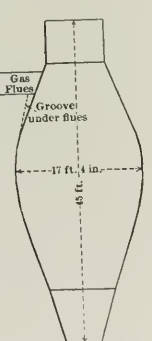
FIGS. 10, 11 AND 12—FURNACE NO. 1



Blown-in, Oct. 20, 1860.
Blown-out, Mar. 31, 1861.
Iron per week, tons, 105.96.
Average grade of iron, 3.34.
Fuel per ton pig, tons, 2.30.
Blast-temp., 500°-600°.
Blast-pressure, pounds, 4.
Number of tuyeres, 5.



Blown-in, June 10, 1861.
Blown-out, Aug. 7, 1863.
Iron per week, tons, 109.22.
Average grade of iron, 3.97.
Fuel per ton pig, tons, 5.
Blast-temp., 500°-600°.
Blast-pressure, pounds, 4.
Number of tuyeres, 5.



Blown-in, Aug. 26, 1862.
Blown-out, Apr. 21, 1865.
Iron per week, tons, 154.69.
Average grade of iron, 4.19.
Fuel per ton pig, tons, 1.82.
Blast-temp., 500°-600°.
Blast-pressure, pounds, 4.5.
Number of tuyeres, 5.

FIGS. 13, 14 AND 15—FURNACE NO. 3

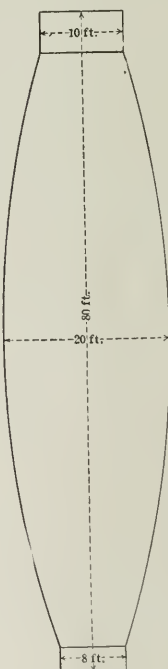
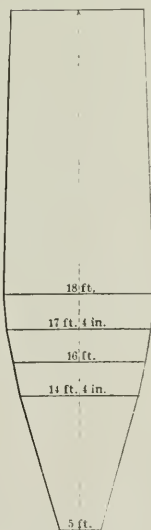


FIG. 19—FURNACE NO. 2 MUSCONETCONG IRON WORKS, STANHOPE, N. J., 1871



Blown-in, Jan., 1874.
Blown-out, Aug., 1874.
Iron per week, tons, 214.74.
Average grade of iron, 3.67.
Fuel per ton pig, tons, 1.52.
Blast-temp., 700°-800°.
Blast-pressure, pounds, 4.5-5.
Number of tuyeres, 5.

FIG. 20—FURNACE NO. 1

any danger from a moderate step in this direction, especially with the increasing hearth diameters now being used.

Of course, in so abstruse and difficult a matter the test of time and experience is the only safe guide.

The evolution of practice from the early days of the anthracite iron industry to its decline about thirty years ago is well shown by Figs. 7 to 22 from Mr. F. Firmstone's paper.

About a generation ago many furnaces were built with a small hearth, a high and very steep bosh, and a top much larger than the hearth. The evolution of standard practice at the two largest furnace plants in the country using Lake ores is well shown by Figs. 23 to 36, reproduced from H. A. Brassert's paper "Modern American Blast Furnace Practice" before the American Iron and Steel Institute in 1914.

The boshes have been lowered virtually 50 per cent, the hearth has been increased about 50 per cent, and the angle of the bosh has gone through a cycle swinging from 79 deg. down to 72½ deg. and now back again to 80 deg. The top diameters have been changed but little, as have the heights, practically all the later ones being 90 ft. These changes have taken place with an increasing rate of production, the net result of which has been to make an increased tonnage per furnace of three to one over the practice of a generation ago.

With this increased output has gone necessarily an increased volume of wind. The resulting increase in pressure has increased the rapidity of combustion and reduced

the amount of space necessary for that operation, so that the zone of fusion and the top of the bosh have steadily fallen. To a certain extent it is proper to say that the blast heats available have increased and that therefore there is less relative increase in volume of the gas column at the top of the bosh as compared with that at the tuyere plane and this has coincided with the increase in the hearth diameter, as it should on the theory of constant gas velocity; at the same time it must be recognized that the desire to produce a greater tonnage per furnace with the consequent necessity of burning more coke, and affording more room for this, has been the chief cause for the latter change.

As to the considerations which effect the slope of the bosh, we know but little. At the beginning of the period covered by the set of profiles reproduced from Mr. Brassert's paper it was quite customary to use very small hearths and steep bosh angles in furnaces much smaller in maximum diameter in the bosh and also at the top than number 1 of this series. For a period of years and within limits it may be correctly said that a proportional increase of both hearth and bosh diameters took place, as it properly should on the theory of constant gas velocity, and this, combined with the lowering of the bosh, had the effect of greatly reducing the bosh angle. That this effect was highly beneficial in some cases, I have seen demonstrated so unmistakably as to leave no room for doubt, but now, as above noted, the tendency is to return to bosh angles of between 77 deg. and 80 deg., and with these angles it is possible to use high blast temperatures with large percentages of Mesaba ore, something it was considered impossible to do for many years, for a reason of which many furnacemen convinced themselves by trial, that furnaces using large percentages of these ores would "stick" if given more than a very moderate amount of blast heat.

The reason for this action is not definitely understood as far as known to me. Presumably it results from the fine subdivision of the ore which, when in a partly reduced condition, enables it to form a plastic mass too early in its descent, if the furnace becomes too hot, and is analogous to the tendency of all furnaces irrespective of the ore they use to stick if they become excessively hot in the hearth.

Whatever may be the cause of this tendency it is now demonstrated that it may be overcome by steepening the angle and reducing the height of the bosh, presumably so as to furnish smaller resistance to the descent of the charge column and thereby counteract the tendency of the charge to hang from being sticky.

With the change in practice worked out at the South Chicago Works of the Illinois Steel Company, described in the papers of Messrs. Brassert and Mathesius, has gone an increase in the pressure-drop for penetration as mentioned earlier in this article. The increase is more than proportional to the hearth diameter through which it must act while the tuyeres used are very long, and it is probable that the resulting acute jetting action virtually builds up the inside of the hearth and on the lower portion of the bosh, owing to the effects described under the head of penetration.

Considering these two circumstances together it may be that the high penetration produces "phantom" bosh and hearth lines on which the furnace really works in operation, the bosh flatter, and the hearth diameter smaller than those provided in the construction and yet short and steep enough to prevent too great support of the stock by the bosh walls in the (upper) pasty zone, thus giving a certain amount of latitude in the working lines of the furnace, within which it may find those best suited to the conditions.

These views in regard to the South Chicago practice are intended merely to be suggestive, they must not

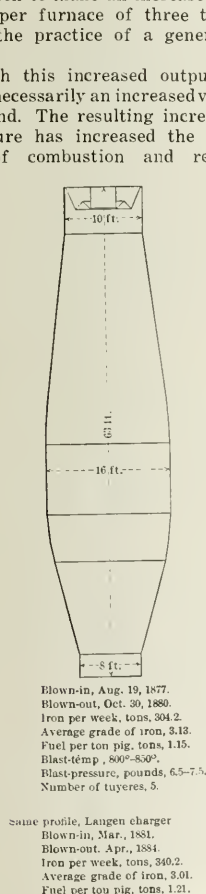


FIG. 21—FURNACE NO. 1,
REBUILT 1875-77

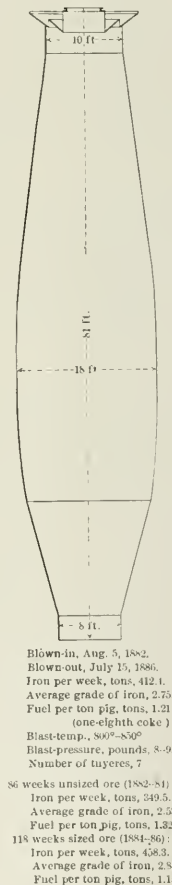
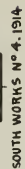


FIG. 22—FURNACE NO. 2,
REBUILT 1881-82



FIGS. 23 TO 36—SHOWING THE DEVELOPMENT OF BLAST FURNACE LINES FROM 1882 TO THE PRESENT TIME, AS ILLUSTRATED BY THE FURNACES BUILT AT THE
EDGAR THOMSON WORKS, CARNEGIE STEEL COMPANY AND THE SOUTH WORKS, ILLINOIS STEEL COMPANY

be considered as established. It must be noted also that this change has been accompanied with an improvement in the quality of fuel used which has enabled practice to be followed which would not have been so successful with an inferior fuel. The concentration of heat with a poorer fuel is not sufficiently great in so large a hearth and a tendency would arise that might be very troublesome for the hearth to build up in the bottom. Even now it remains to be demonstrated that a sufficient concentration of heat in the hearth can be made with these furnace lines to produce foundry and other high-silicon irons, furnaces of this type having made their records on steel-making irons low in silicon, and having definitely failed to produce foundry iron satisfactorily in some cases.

Reviewing all these complex considerations many of them obscure and difficult to understand and all almost virtually impossible to measure, it becomes evident that the mechanical principles of the blast furnace are not second in practical importance to the chemical and thermal principles and that if furnaces are to yield a satisfactory commercial result we must consider with the utmost care not alone chemical equations and heat balances which often largely take care of themselves any way, but questions of regular and uninterrupted descent of the charge column, leading to low fuel consumption, low flue-dust loss and regular product, of low and uniform blast pressure permitting the use of small and inexpensive power plants and small consumption of furnace gas, and other purely mechanical questions.

It is a safe statement that if one-half the scientific research had been expended on these practical mechanical questions that has been spent on chemical equilibria and lopsided heat balances the science and art of furnace operation would be far ahead of where they are to-day.

The Production of Ammonia from Cyanamid

A paper read at the Baltimore meeting of the American Institute of Chemical Engineers on January 12, 1916.

BY W. S. LANDIS

After working for many years on the problem of the fixation of atmospheric nitrogen in the form of cyanides and cyanamids, Professors Frank and Caro of Berlin were forced by the outbreak of the Boer war to turn their attention to the utilization of their products otherwise than in the field of precious metal extraction. A consequence of the then existing economic situation was the discovery of the process of transforming the cyanamid compounds into ammonia. United States Patent No. 776,314, granted Nov. 29, 1904, most probably represents the first American publication on this subject.

According to the specifications of this patent various cyanamid compounds and derivatives, including the crude form of the calcium salt sold under the name of lime nitrogen, when treated with steam or water in the proportion of three molecules of water to two atoms of the nitrogen in the cyanamid salt, will yield ammonia. It is recommended in the specifications that the reaction be carried out at temperatures from 160 deg. to 180 deg. C. in a closed vessel, though the claims of this patent cover temperatures above 100 deg. C.

There has grown around this process and its later refinements in the last fifteen years an extremely important ammonia industry. Naturally the greatest development has been in Europe, its home, and it is only within the past year that a plant comprising full-size apparatus has been in operation in the United States. In attempting to catalog the various plants throughout the world which have been converting cyanamid into ammonia in large-scale operations, I find that avail-

able information, particularly since the outbreak of the European war, is so incomplete that the listing in consequence was very inaccurate. It is certain, however, that the transformation of cyanamid into ammonia is successfully carried out in Norway, Germany, France, Switzerland, Italy and Japan, and prior to the war in Belgium, the bulk of the product going into ammonium sulphate for the chemical and fertilizer trade. Norway is producing large quantities of ammonia used in the Birkeland-Eyde plants for the production of ammonium nitrate; France has produced considerable quantities of anhydrous ammonia by this process; at the present time Germany is producing enormous quantities of nitric acid from this cyanamid-ammonia by a newly developed oxidation process, and is erecting cyanamid plants equipped with ammonia apparatus at various places.

The fixation of atmospheric nitrogen, chiefly due to our Government's policy in respect to water power development, has not been practised in the United States. During the year 1914 contracts were let in Germany by the American Cyanamid Company for the equipment of the largest single ammonia plant then projected or operating in the cyanamid industry, but the outbreak of the European war interfered with the shipment of this apparatus, nearly all of which was seized by the German Government for the purpose of providing for its own explosive requirements. It was possible to bring only a small portion of this equipment over to the States, where it was set up and put into operation, and is now producing several tons of pure ammonia gas per day. This plant has been in continuous operation here for six months without any signs of trouble whatever, and is considered to be most successful and satisfactory in every way.

RAW MATERIALS

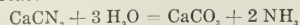
The crude cyanamid or lime-nitrogen is now a well-known commercial product. The Canadian factory supplying the United States and its insular possessions with this product has a capacity of fixing nitrogen equivalent to 90,000 lb. of ammonia per day, and with the completion of certain additions now being made will be capable of supplying some 110,000 lb. of ammonia each 24 hr. The demands for this product, most of which goes into the fertilizer industry, are so great that the plant is now operating at its full rated capacity. It is therefore evident that the supply of raw material for an ammonia industry is in no sense limited.

Crude cyanamid, or lime nitrogen, the reagent used for the production of ammonia, is an electric furnace product, whose production has been described elsewhere* by the writer. This material as turned out of the furnace, contains nearly 25 per cent nitrogen in the form of CaCN_2 , 12 per cent CaO and 12 per cent carbon, with miscellaneous impurities derived from the various raw materials entering into its manufacture.

The other raw materials entering into the ammonia process are soda ash and hydrated lime. The quantities used are small, being approximately, $3\frac{1}{2}$ per cent and 2 per cent respectively of the weight of lime nitrogen used. Steam and power requirements which vary with the size of the plant are discussed later.

CHEMISTRY

On treating lime nitrogen with steam, ammonia is produced from the calcium cyanamid according to the following reaction:



The reaction is almost quantitative when carried out

**Metallurgical and Chemical Engineering*, vol. XIII, p. 213. (April, 1915)

on a large scale according to the process to be described later in detail. This reaction is exothermic in character, and while the exact heat of formation of calcium cyanamid has never been determined accurately, it is believed that the heat evolution from the decomposition of the cyanamid alone amounts to between 200 and 300 lb. calcs. per pound of ammonia evolved. This plays an important part in the present method of carrying out the process, inasmuch as after once starting the reaction under proper conditions it will proceed of itself, and, in fact, with such great velocity that only complicated and highly developed apparatus can take care of the gaseous products.

The process as carried out in the plant operating in the United States is essentially that described in the specifications of United States Patent 1,149,633, dated Aug. 10, 1915, "Process of Making Ammonia from Calcium Cyanamid."

In order to take advantage of the exothermic character of the reaction, as above stated, the process is made to take place in an autoclave partly under high pressure. This apparatus consists of a steel tank approximately 6 ft. in diameter, 21 ft. high and capable of operating under a working pressure of 300 lb. per square inch. It is provided with a powerful stirring apparatus. Into this autoclave is charged about 12,000 lb. of mother liquor derived from a previous operation (fresh water to start), and lime nitrogen is slowly fed into this liquor under continuous agitation. As the lime nitrogen contains always a fraction of a per cent of undecomposed carbid, acetylene is evolved during this dissolving of the lime nitrogen. A proper ventilating system is provided to remove this acetylene at such dilutions as will be non-explosive even if subjected to a source of ignition. The charging is usually carried on over a period of an hour so as to insure a thorough incorporation of the lime nitrogen with the solution and the breaking up of all lumps in the slurry.

When the lime nitrogen has all been added to the autoclave the reagents—soda and lime—are added for the purpose of increasing the efficiency of ammonia evolution, principally through prevention of the formation of polymeric forms of cyanamid compounds which are difficult of transformation into ammonia. The autoclave is then closed up, and steam is admitted for approximately 15 min., or until the pressure gage on the autoclave indicates three or four atmospheres, which shows that the temperature in the autoclave has been raised sufficiently to start the reaction at a fair rate of speed. The reaction then proceeds of itself, generating ammonia and steam in the autoclave, and it is necessary to relieve this gas accumulation by means of

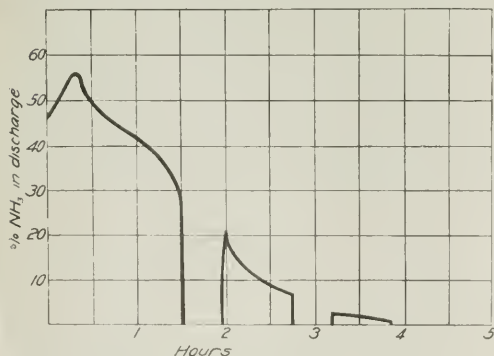


FIG. 1—VARIATION OF COMPOSITION OF AMMONIA-STEAM MIXTURE DISCHARGE

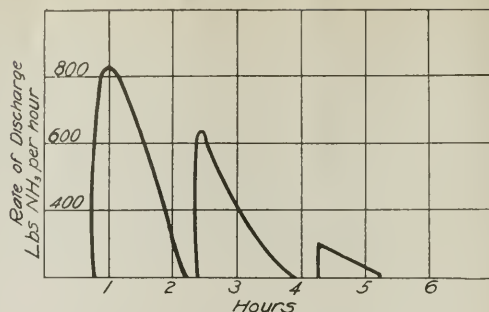


FIG. 2—VARIATION OF RATE OF DISCHARGE

suitable valves to avoid excessive pressures in the apparatus. The rate of reaction becomes cumulative as the temperature rises, and this relief of ammonia and steam must be permitted. Under normal working conditions the pressure in the autoclave will rise to about twelve or fifteen atmospheres in the course of about 20 min. with the relief valve open. The pressure then drops off slowly, as the gas is discharged, the rate of discharge being usually regulated by the attendant at the valve so as to maintain a constant pressure in the ammonia line, and at the end of about one and a half hours from the start of the operation the evolution has usually stopped.

Nearly all of the cyanamid in the charge has been decomposed during this first period of the operation, but the solution is still highly charged with ammonia, which it is necessary to expel. A very small amount of undecomposed lime nitrogen may be left, particularly of polymerized forms, which yield up ammonia only slowly. The steaming operation is then repeated, this time introducing steam until the pressure of the autoclave goes up to six to eight atmospheres. The ammonia discharge valves are again opened until the autoclave is discharged, requiring a period averaging approximately one-half hour for this second discharge.

In order to insure practically complete evolution of all the ammonia in the autoclave it is advisable to again repeat the steaming to six to eight atmospheres for a third period, discharging as before. During this last period of steaming and discharge rarely over 2 per cent of the total ammonia as charged is evolved, and it can, therefore, be omitted if extraordinary demands on the capacity of the apparatus are made.

Extended studies of the course of this decomposi-

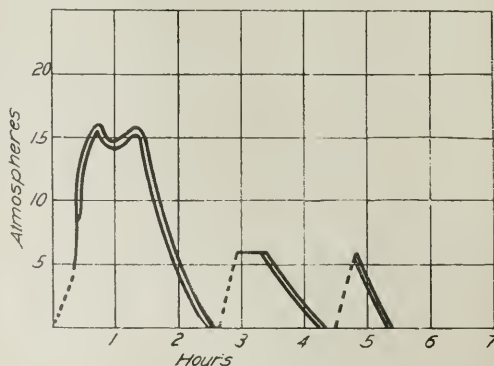


FIG. 3—VARIATION OF PRESSURE IN AUTOCLAVE

tion of lime nitrogen in the autoclave have been made both abroad and in this country, and are here reproduced in the form of charts. The discharge from the autoclave consists of a mixture of steam and ammonia, the composition progressively changing during the cycle. This variation in composition is shown for an actual operation carried out in this country in Fig. 1, in which the ordinates represent the percentage of NH_3 by weight in the ammonia-steam mixture discharged from the autoclaves, and the abscissa the time after start of the operation, analyses of discharge being made at approximately 3-min. intervals.

The rate at which ammonia is discharged from the autoclaves under operating conditions varies with the imposed condition. It has been found that most requirements are met by discharging at such rate as to maintain a constant pressure of steam and ammonia in the main leading from the autoclaves. Under such conditions the rates of discharge during a given operating cycle are represented by the curve in Fig. 2, in which the ordinates are the pounds of ammonia discharged per hour, and the abscissa again the various elapsed times from the start. In this case the charge in the autoclave was 7000 lb. of lime nitrogen analysing about 26 per cent equivalent NH_3 .

Where a uniform supply of ammonia is required it can be obtained by the insertion of a special type of gasometer in the system. Also suitable grouping of a number of autoclaves and cyclical operation of the same will assist greatly in obtaining a uniform rate of production without the use of such gasometer.

In Fig. 3 is shown a curve of the pressures existing in a European autoclave, slightly smaller than the one described above, and operating on a charge of 8000 lb. of lime nitrogen. The dotted lines represent the admission of steam, and the full lines the pressures as shown on the gage on the autoclave. The ammonia discharge valves of the autoclaves are opened where the lines are indicated double.

At the close of the operation the bottom discharge valve is opened and the mud contained therein runs by gravity into large suction filters of the well-known "Nutsche" type. Here the liquor is sucked off from the solid constituents, a thorough wash with water is given and the sludge removed to the dump. Under normal operating conditions this sludge when dried contains less than 0.2 per cent of equivalent ammonia, and about 65 per cent of CaO in the forms of carbonate and hydrate. It is dark gray or black in color, due to the carbon present, and finds application as an agricultural lime. The liquor removed from the filter is used in dissolving the next batch.

HANDLING THE GAS

In the manufacture of ammonium sulphate, as carried out extensively abroad, the mixture of steam and ammonia coming from the autoclave is led directly into an absorber and produces a high-grade white sulphate. This production of sulphate is much simpler than from ammonia liquor. Where the introduction of the accompanying steam is not permissible, as in the production of certain ammonia salts which cannot be subjected to high temperatures, or where the process involves subsequent evaporation and crystallization, the ammonia-steam mixture coming from the autoclave is passed through a simple rectifying column provided with dephlegmator and condenser, and there is obtained therefrom a practically chemically pure ammonia gas, saturated with moisture at the temperature of the condensing water. This rectifying column is self-acting because of the large quantity of steam admitted with the ammonia-steam mixture, and requires no attention whatever in its operation other than to shut off the cooling water to the condenser when not in use.

The ammonia derived from the column, as before mentioned, is practically chemically pure, and is used directly in a large number of chemical industries. The Birkeland-Eyde engineers absorb this ammonia gas in distilled water, forming a dilute aqua ammonia, which they add directly to their dilute nitric acid for the manufacture of ammonium nitrate, the product being of extraordinary quality. On the other hand, ammonium nitrate of equal grade may be produced directly from the ammonia gases dehydrated in the column without the water absorption step.

One of the large autoclave plants in France has been manufacturing anhydrous ammonia for years, and in addition to the above purification system they have installed an oil washer, charcoal filter and lime-drying boxes before liquefaction. The oil washer, the writer was informed, was installed to remove some very minute traces of an unknown organic compound, but he has inferred that the character and quantity of this impurity, from the manipulation of this apparatus, is largely mythical.

For the production of nitric acid from ammonia, the product as taken from the condensers attached to the ammonia column is so pure that no trouble is occasioned by the poisoning of the catalyzers used in its subsequent oxidation.

COMPLETE PLANT

An autoclave plant* of 15 autoclaves, such as supplied the Birkeland-Eyde Co., which is similar to those intended for this country, has a rated capacity of 75,000 lb. of ammonia gas per day. The general arrangement of the apparatus, piping, etc., is clearly shown here by the use of colored inks, and I am sorry that photographic reproduction does not bring out the details of these drawings so that they can be shown in a more convenient form. Owing to the present inability to obtain this apparatus from Germany, where it has been manufactured on an extensive scale, the American Cyanamid Company has redesigned the whole equipment, adapting it to American standards and manufacturing conditions, and is now building this equipment in the United States.

EFFICIENCY OF DECOMPOSITION

An extended study made by the writer a year ago of one of the European plants which had been in operation for a long time, showed that the transformation efficiency of the nitrogen in the lime nitrogen into ammonia was over 99 per cent. Our American plant is showing operating efficiencies covering a period of several months substantially equal to the above.

AUTOCLOVE PLANT

An economical autoclave unit is one of eight working shells. As the operating load factor on these autoclaves is very close to 100 per cent it is not necessary to supply more than one spare shell to this eight autoclave equipment to insure a full 100 per cent load factor. Such a plant of eight autoclaves would require a 300-hp. boiler. It was the old practice abroad to set the safety valve on the autoclave shells at 20 atmospheres and operate the boiler at this same pressure. In our own designs here in the States we have successfully operated at 125 pounds steam pressure without trouble and can take steam from a common plant main. Superheated steam is preferable for the purpose, but not absolutely necessary. There is in addition required for operating the lime nitrogen feeding device, the stirrers in the autoclaves, the vacuum pump and the air compressor, and miscellaneous sludge disposal equipment a continuous motor load of approximately 100 hp. (the connected

*Drawings of this plant were exhibited by the author at the meeting.

motor load would probably average about 200 hp., depending upon local conditions).

OPERATING COSTS

In the compilation of a cost sheet for the production of ammonia from lime nitrogen there is such great latitude in unit costs concerned that the writer is presenting rather full quantitative data, to which he is appending assumed unit costs. In most cases the assumed unit costs are averages existing before the outbreak of the European war, and to which an approximate return may be expected after its close. In any case they may be readily corrected to meet local conditions.

Lime nitrogen: 26 per cent ammonia. It is unquestionably the cheapest source of nitrogen (ammonia) in this country. The sales prices are dependent to an extent upon the quantities and deliveries contracted for. The freight is allowed at \$3.00 per ton of lime nitrogen shipped in special containers, which should cover the greater portion of territory in the United States lying within a 500-mile haulage radius of Niagara.

Caustic lime is to be air slacked on spot, 2 per cent weight lime nitrogen used assumed at \$6.00 per ton delivered.

Soda ash 3½ per cent of weight of lime nitrogen at \$16.00 per ton delivered.

Power, 100 hp. continuous at 1c. per hp. hour.

Steam at 30c. per 1000 lb., 60 per cent weight lime nitrogen.

Water, 2 U. S. gal. per lb. ammonia. As the larger part of this is used in condensers and coolers the greater proportion may be salt water. Assumed at 2c. per 1000 gal.

Labor and superintendence: Assumed at 300 men hours per day at 30c. per man hour.

Repairs and renewals: \$1.50 per ton ammonia, a record of long-time operations.

Interest: Assumed at 6 per cent on plant cost of \$120,000.

Depreciation: On plant cost of \$120,000 depreciated in ten years, say, 8 per cent.

OPERATING COST OF AMMONIA PLANT

Capacity 30,000 lb. ammonia per day, gas saturated with water at cooling water temperatures.

Item	Quantity	Rate	Per Day	Per Pound Ammonia
Freight	.....	\$3.00	\$150.00	\$0.00600
Lime	1.20 tons	6.00	7.20	0.00024
Soda	2.10 tons	16.00	33.60	0.00112
Power	2,400 hp. hr.	.01	24.00	0.00080
Steam	72 M lb.	.30	21.60	0.00072
Water	60 M gal.	.02	1.20	0.00004
Labor	300 men hr.	.30	90.00	0.00300
Repairs and renewals	.....	.....	22.50	0.00075
Interest	.....	.....	20.00	0.00067
Depreciation	.....	.....	26.66	0.00089
Miscellaneous	.....	.....	24.67	0.00082
Total conversion cost, excluding NH ₃ losses.		\$451.43		\$0.01505

COST OF PLANT

On account of the varied building conditions existing throughout the country it is almost impossible to give a detailed estimate of the cost of plant. A recent projection of such costs made by this company for a plant of this size, from which I have deducted the cost of land, foundations and sludge disposal, shows that an ammonia plant of the size herein described could be erected for about \$120,000. This plant is designed to produce an ammonia gas as its final product cooled to the temperature of the available water of the condensers, and, therefore, not strictly anhydrous. This figure further assumes that water and power are furnished the plant, and no provision is made for power or pumping plants.

Steel buildings with corrugated iron sides and roof, and of a type which have demonstrated themselves as fairly satisfactory for this service are included. The

limitations imposed by building laws and choice of architecture may force one to materially modify this estimate, as cheaper forms of construction may be used. On the other hand, many may prefer a more elaborate type of building than provided in the above estimate, which would materially raise this figure.

SUMMARY

The large number of installations operating with perfect success in various parts of the world for a number of years have demonstrated the commercial possibility of making ammonia from lime nitrogen. The plant in its present highly developed state is extremely certain in its action and simple to operate. The efficiency obtained in the transformation of the nitrogen in lime nitrogen into ammonia gas is upward of 98 per cent, or almost quantitative. The consumption of reagents is remarkably small, and they are cheap and easy to obtain in almost all parts of the world.

The quality of the ammonia produced by this process is not surpassed by any in the United States. It is chemically pure as produced and requires no further costly and tedious purification to render it available for the highest grade chemical products, or for the production of liquefied anhydrous. The actual cost of production of this high grade pure ammonia on a considerable scale, which enables one to take advantage of the lower prices at which lime nitrogen is offered, brings high grade cyanamid-ammonia into the market almost as cheaply as the more impure forms already found there, and very much cheaper than it is possible to obtain an equal quality of ammonia from gas-house liquor, the coke ovens, etc.

American Cyanamid Co.,
Niagara Falls, N. Y.

Non-Ferrous Metal Market

Copper—According to the Geological Survey the copper production for 1915 was the greatest on record. The smelter production is estimated at close to 1,400,000,000 lb. The average price for the year was about 17.3 cents as compared with 13.3 cents for 1914. At the present time no one but the producers knows how scarce the metal really is. Since our last report the price has risen from 21.75 to 24 cents although no enormous amount of buying has been recorded. The last quotation was 24 cents on Jan. 12.

Tin—Imports for the year 1915 from all sources according to the New York Metal Exchange were 47,835 long tons as compared with 40,887 long tons in 1914. The average price for the year was 38.66. During the last two weeks the market has been excited and spot tin and early deliveries have been difficult to buy. The price advanced from 39.12½ on Dec. 28 to 44.75 on Jan. 5 since when it has reacted to 41.25 to 41.50.

Lead—The production of refined lead in 1915 according to the Geological Survey estimate was 565,000 tons as compared with 542,122 tons in 1914. The maximum price was 7.56 cents on June 14, the average for the year being 4.7 cents as compared with 3.9 cents in 1914. During the last two weeks three advances have been made by the Trust. On Dec. 31 the price was advanced to 5.50 on Jan. 4 to 5.75 and on Jan. 7 to 5.90.

Spelter—The estimated spelter production for 1915 was 492,495 short tons as compared with 362,361 short tons in 1914. The market during the last two weeks has been quiet but firm, with prices practically unchanged at 17.42½ to 17.67½.

Other Metals—Aluminium is quoted at 54 to 56 unchanged. Antimony is scarce and is quoted at 42.50. Silver is quoted at 56½. Quicksilver has risen to \$175 per flask.

The Grading Industries

BY EDWARD S. WIARD

I have given the above title to certain industries, not because grading is the essential operation in them, being in most cases but an auxiliary one, but rather to discuss under this convenient title some mechanical problems which arise in industries in which grading is one of the necessary steps. Before the completion of the articles it will be seen how great is the scope of the "grading industries" and how much of interest there is in their history, statistics, technology and trade. The plan of the articles will be to describe first the "tools" used in grading. Following this portion of the articles, which will take up the theory of the action of grading devices and practical considerations governing their design and the kind of material for which they are especially suited, the grading industries will be taken up in alphabetical order.

The word "grading" is used in these articles in the sense of preparing material according to size or sizes, and in the majority of the grading industries the sizing is the finishing operation, following which products are ready for the market. In many cases they are ready for the consumer and in the rest they are ready for the initial operations of other industries. The majority of the grading industries have to do with the preparation of raw material which reaches the consumer indirectly through its use in other arts and manufactured products. Sulphur used in many arts and talc employed as a filler for wallpapers, for talcum powder, etc., are examples of graded products which reach the consumer indirectly. As examples of graded products which directly reach the consumer may be mentioned black gunpowder, flour and food products of many kinds, such as rice, peas, beans, coffee, etc. In the case of food products grading is done primarily to please the eye and to a minor degree for sanitary reasons. Crushed seed and fruit would invite decay. In the case of peas and beans uniformity of size also makes for uniformity of cooking.

Distinctions in Grading

In the subject of grading, distinction must be made between the breaking up of a granular or fragmental mass or masses of objects of the same or nearly the same general shape into a number of sizes, and the mere splitting of such masses into two, one fine and the other coarse, one or both being saleable but usually only the finer one. Where the fine material is the merchantable product the coarser part is either allowed to go to waste or, as is most commonly the procedure, it is subjected to comminution to obtain a complete yield as a fine product. This is usually done continuously; that is, the comminution means are closely connected with the separation means, the reject of coarse material from the latter flowing directly back to the comminuting devices. This mode of operating produces what is known as a "closed circuit," and what this means and its effect on the rate of feeding of the comminuting device is described in the reference below.¹

Examples of splitting grading can be found in the preparation of talc for paper filling and talcum powders, flour, artificial and amorphous graphite for pencil making and high-grade lubricants, pumice for scouring-soap powders, infusorial earth for incorporation with high explosives, separation of sand and slime in the cyanide process for gold extraction, preparation of pigments, etc. Some of the modes of effecting the splitting are by dry screening—flour, pumice and sulphur being examples of this mode of separation; by air separation—natural amorphous graphite and pigments

being examples of this mode of splitting. In both of these cases separation and comminution go on continuously, the end result being to reduce all the material treated to a finely divided saleable product.

In some industries the employment of a splitting grading or separation would yield a superior product, but the expense attending the use of separating means would be out of proportion to the value of the better product obtained. Again the possible means which could be employed would not be efficient, or the most effective process which could be employed would spoil the product made. In preparing feldspar for pottery purposes or abrasive soaps the finishing grinding is done in a tube mill. For the first purpose the spar is ground from four to six hours, when over 96 per cent will pass a screen with 200 openings to the linear inch. For soap purposes the spar may be ground for as long a period as ten hours. In these cases it must be evident that while a very finely divided product is desired there must be a large proportion of the spar which is ground unnecessarily fine in order to be sure that no grit remains in the finished material. If the spar were submitted to a water separation the fine material would have to be dried and it would be spoiled by caking. Efficient dry separation processes would not be applicable because of their expense and limited capacity. The best ground feldspar is worth about ten dollars per ton.

In the manufacture of Portland cement the use of a wet separation method would, of course, be out of the question, and dry separation by air would not be applicable for the reason stated above. As in the case of feldspar much material must be ground unnecessarily fine to be sure that all the product will be reduced to the proper limiting size which, in the case of cement, means that 75 per cent or over must pass a 200 mesh sieve. Portland cement has sold as low as \$0.65 per barrel weighing about 380 lb. How fine a cement particle must be ground has not been definitely fixed by experimentation but there is no doubt that there must be a certain sized particle below which in point of size all the particles are cementing material and above which they are not.²

An unusual separation occurs in the shot-making in-

¹The available data on this point will be discussed later.

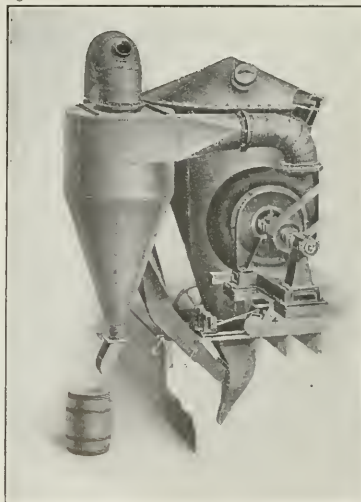


FIG. 1—VACUUM SEPARATOR

²Theory and Practice of Ore Dressing. Wiard. p. 203 et. seq.

dustry. The superior rolling quality of the more perfectly rounded shot is taken advantage of in separating the perfect from the imperfect shot. The ungraded material is fed to a conical revolving surface at one point near the top of the cone. The more perfect shot will roll almost directly down to a discharge point along the edge of the cone which is almost directly below the feeding point, while the imperfect shot will roll more slowly and under the additional influence of the rotation of the conical surface report at points ahead of that where the perfect shot discharge.

Methods of making a series of gradings by fall of particles in currents of air, water or other fluids are described at a later point in the articles. This method of grading may also be employed to effect a splitting grading or separation. If air is used, large dust chambers will be required to settle the fine dust.

Grading by Air Separation

The Raymond air-separation apparatus is shown in Figs. 1 and 2. The material is fed in by an enclosed hopper at point 4. It is then drawn up between the inner and outer cones 7, the sectional area of the passage increasing toward the top or deflector 8. Between this point and the down-draft pipe 9 most of the coarse material will fall back and return to the comminuting device if one be provided below the feed point 4. The fine particles pass through the fan 6 and then through the collector 11 where the current of dust-laden air is given a centrifugal spin and drops the bulk of the finely divided material which can be collected at point 14. From the separator the air returns to point 4 by way of passage 3. It will be seen from this description that the device requires no dust chambers, for the air current is in a closed circuit and is used over and over again. While the air current returning to the feeding

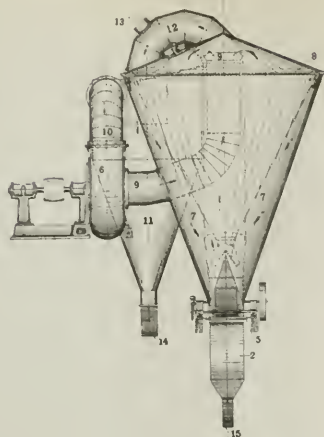


FIG. 2—SECTIONAL VIEW OF VACUUM SEPARATOR

device may contain some fine material, this can be largely obviated by collection chambers of the proper size and regulation of the volume of air forced through the apparatus. Some regulation can be gotten through the wind gate A, Fig. 1. The Raymond apparatus is excellent for producing limited tonnages of impalpable powder. It is much used for preparing finely powdered drugs, pigments, graphite, etc.

Examples of Grading Incorrectly Termed "Classifying"

In the cyanide process for gold extraction and in a number of Western ore mills various forms of splitting grading devices are used to which the name classifier is wrongly given. The principal machines of this type are the Dorr, Akins and Federal-Esperanza, illustrated in Figs. 3, 4 and 5 respectively. In all these machines the material is fed in, mixed with a certain proportion of water, the amount of water being about six parts by

TABLE I		
	Akins	Dorr
Ratio water to ore	5.11	4.62
	Per Cent	Per Cent
Dry ore	16.38	17.64
Water	83.62	82.35
Tons, 24 Hours:		
Solids	92.76	76.20
Water	473.21	355.75

Sizing Tests		
Material Fed	Per Cent	Per Cent
On 20-mesh	1.5	1.5
On 40-mesh	10.0	13.5
On 60-mesh	14.0	15.0
On 100-mesh	13.5	12.5
On 200-mesh	17.0	15.0
Through 200-mesh	44.5	42.5

Sand Delivered		
	Per Cent	Per Cent
On 20-mesh	1.6	2.7
On 40-mesh	22.8	26.5
On 60-mesh	35.2	29.5
On 100-mesh	24.4	20.5
On 200-mesh	11.6	14.8
Through 200-mesh	4.4	6.0
Moisture	26.8	30.5

Slime Delivered		
	Per Cent	Per Cent
On 100-mesh	4.0	2.8
On 200-mesh	18.0	16.4
Through 200-mesh	78.0	80.6

Federal-Esperanza		
Mesh	Material Fed, Per Cent	Sand Delivered, Per Cent
On 40	5.4	...
On 60	15.1	...
On 80	9.8	...
On 100	8.3	...
On 150	1.4	...
On 200	21.4	...
Through 200	1.6	...
	50.0	...
Slime Delivered, Per Cent		
	13.0	92.0

weight of water to one of ore. If the amount of water coming to the classifiers exceeds this ratio it is properly reduced in Western practice by suitable dewatering devices. In cyanide mills either the Dorr or Akins type is used. The Federal-Esperanza classifier has been used to some extent in Western concentrating mills. Table I illustrates the capacity and work of the three classifiers.

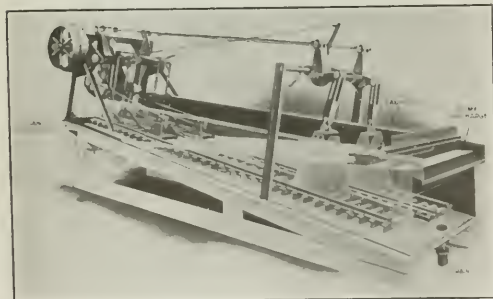


FIG. 3—DORR CLASSIFIER

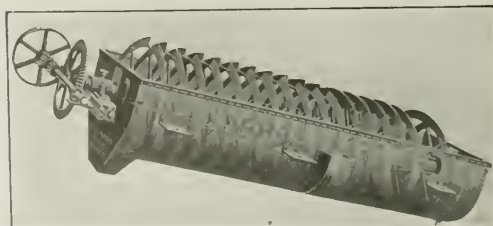


FIG. 4—AKINS CLASSIFIER

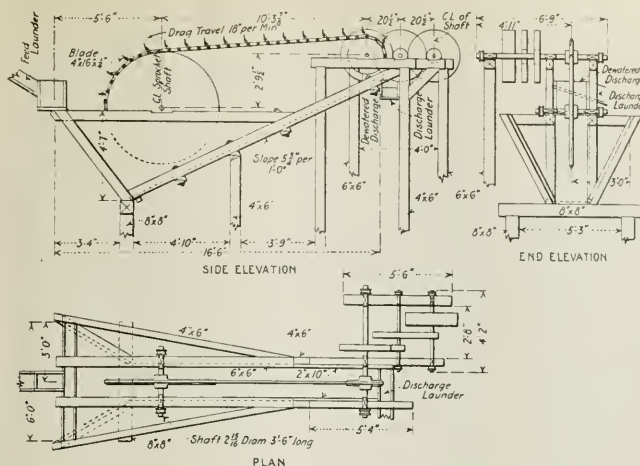


FIG. 5—FEDERAL-ESPERANZA CLASSIFIER

The figures in the case of the Dorr and Akins are comparative, having been made in the same mill and on the same material.

The Dorr classifier, as a glance at the figures of this machine will show, uses a flight-pushing device. On the upward or push motion of the blades they dip into the sand, and on the return motion they are raised above the sand. The advancing means of the Akins is merely a double spiral which is open in the center to allow the water and slime to drain back. The Federal-Esperanza classifier is an endless belt to which are secured flights or vanes. The speed of the belt is from 15 ft. to 30 ft. per minute. The capacity of the individual flight is about 0.2 lb. per square inch of flight surface.

The power required for driving any of the machines does not exceed 0.01 to 0.02 hp. per ton of the dry material treated daily. Considering all the merits and demerits of the three types there is not much choice for excellence among them. If the Federal-Esperanza be in first-class condition with the conveyer chain properly drawn up so that it does not drag upon the bottom of the tank it should show the smallest power consumption of the three, followed by the Dorr and the Atkins; that is, the unit power consumption or consumption per ton of sand delivered. The wear of the conveyer chain from grit may, however, cause it to drag upon the bottom of the tank, materially increasing the power consumption.

More capacity can be gotten from the Federal-Esperanza type for the area of individual blade employed since the conveying operation is continuous. In the case of the Akins, capacity for any particular size of spiral is limited by the fact that if it is run at too great a number of revolutions it will merely slide through the sand and not push it ahead.

In the matter of attention to lubrication and general oversight to see that the machines are functioning properly, the Akins machine should require the least attention and the Dorr the most.

In the matter of wear and tear of the rakes or moving means, the Akins will report the most, and between the Dorr and Federal-Esperanza there will not be much to choose.

In the matter of starting up after flooding and with the tanks full of sand it will be found that the Akins may often be started without digging out, while with the other two kinds this operation will be necessary.

The Dorr machine is provided with a device for rais-

ing the rakes before shut-downs but if the machine is flooded unexpectedly this device will not be of much use.

In the matter of cleanness of products the Akins delivers the cleanest sand product and the Federal-Esperanza the most contaminated one, but there is not much to choose in this respect between the Akins and the Dorr. The Federal-Esperanza delivers the cleanest slime of the three, the Dorr being the poorest in this respect, though there is but little practical difference between the Dorr and Akins on this point.

The Federal-Esperanza type is the oldest of the three and before this device was put upon the market Western millmen had made use of similar forms. The principal improvement of the Federal-Esperanza design is the use of a sprocket wheel of sufficient diameter that its bearings may be carried well up above the water and grit in the tank below. In the manufacture of white

lead a classifier similar to the Federal-Esperanza had been in use for many years prior to the advent of this machine for separating the uncorroded portion of the buckles following the corroding and grinding operations.

The most interesting grading operations from a technical point of view occur in those industries where it is necessary to split a mass of material into three or more sizes. Grading of this kind can be done according to diameter or some other linear measure, or two linear measures; as, for example, in the grading of disks of varying size and thickness, by volume, by gravitation in fluids or by weight.

Necessity for Grading in Certain Industries

Some reasons for dividing a loose or broken mass of material into a number of sizes will be gathered from the following examples of the need of this operation in

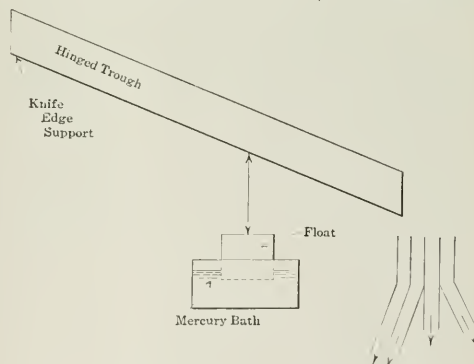


FIG. 6—MERCURY FLOAT FOR GRADING BY WEIGHING

certain industries and uses. In the use of abrasives the aim is to produce a smooth or polished surface from a roughened one. To gain time the roughened surface must be reduced progressively by abrasive grains whose diameter is roughly proportional to the depth of the projections of the roughened surface. Quite evidently, while the abrasive grains are tearing or breaking away the projections of the surface, they are grooving the smoother portions to an amount proportional to the size

of grain used, though to a lesser degree. On this account, if the ultimate aim is a smooth or polished surface, the abrasive must be used in graded masses starting with a coarse size and ending with a fine.

For human and animal consumption salt is graded to obtain varying rates of solubility. For household use a quickly dissolving product is desired, while for layering meat the salt is desired in a condition where it will dissolve slowly. This requires that household salt be finely divided and yet not so finely powdered that it loses its crystalline character, and in a damp climate becomes caked in the receptacles for holding it. If fine salt were used for preserving meat it would quickly dissolve in the moisture of the flesh and run to waste permitting the entry of decaying agencies. A very coarse salt is consequently used for layering meats, intermediate sizes between this and the finest being used where greater rates of solubility are desired.

Coal is almost entirely graded because of the household demand that this material be so delivered. It is quite evident that the limited size of household fire-boxes will preclude the use of very large masses of coal. Again the limited height of household chimneys, or what is the same thing, the low velocity of the draft, forbids the use of much fines in the coal since it reduces the velocity of the gases in passage from the hotter part of the fire to the colder. On the other hand the surface exposed to the gases increases as the size of the particle decreases. For household purposes the best mean between long, crooked, narrow interstitial passages and area of pieces exposed to inflaming gases is somewhere between 1-in. and 4-in. pieces. If a quick fire is desired the best size will be somewhere near the lower limit of size. If it is desired that the fire burn to a bed of glowing coals and that the fire remain in this condition the greatest length of time, then a coal nearer to the larger size given will be selected.

The technology of grading by the use of screens and the means for obtaining volumetric grading will be left to the end of this section, and miscellaneous methods of grading will be taken up first, followed by modes of grading by fluids.

Miscellaneous Modes of Grading

U. S. Patent 1,080,088, Dec. 9, 1913, is for means of separating shrunken and discolored beans from perfect white beans. In this patent means are provided for bringing the beans singly to a position in front of a hinged spout. Means are provided for reflecting all the light from the beans on a selenium cell which consists of narrow strips of narrow strips joining broad brass plates forming portions of an electric circuit. If the hinged spout be supported by a magnet which is part of the selenium cell circuit, then when

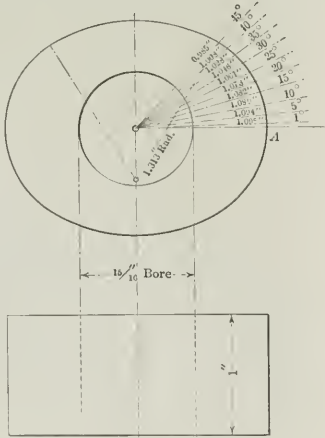


FIG. 7A—SINE BLOCK FOR GRADING BY WEIGHING

the perfect beans pass through the apparatus, since the resistance of the circuit will be diminished from the greater light impinging on the cell, the spout will be raised to the highest point and if a receptacle is placed in the proper position below the edge of the spout, the perfect bean will fall into it. If receptacles are placed behind the first one a gradation can be obtained from perfect to dark, shrivelled beans. According to Adams, greenish yellow rays lower the resistance of selenium the most. The device described or something similar may offer a means of grading according to color, and perhaps of separating ore from gangue.

A silk-sorting machine is one for grading threads of silk according to thickness and winding them upon the proper bobbins. The proper bobbin is presented to the thread by the action of a lever which is governed by the thickness of the thread passing between gage-rollers.

Grading by weighing is only adapted to relatively large individual pieces. Each unit of such a device must have means for feeding the individual masses singly, and the interval of time must be sufficient to completely weigh and dispose of a piece before another passes over the grading means. The transportation element must not influence or interfere with the weighing element. A simple mode of obtaining grading by weighing would be to have a spout hinged at one end and supported by scale-beam connections at the other. Either of the devices shown in Figs. 6 and 7 would furnish the proper weight-opposing thrust Fig. 6 being a mercury float and Fig. 7 a sine curve weight-opposition, the spout hanging from or being supported by a strap or arm in contact with the curved surface which is at point A when the device is at the no-load position. With either of these devices means are provided for giving equal angular depressions of the spout for equal increased increments of weight. As with the selenium-cell device, if suitable receptacles be placed at the proper position below the hinged trough they will receive masses of equal weight.

Grading by Blowing

In grading by blowing, the air most commonly is introduced at the feeding point and from this point the air is expanded into a chamber of increasing cross section. The air may also be exhausted at the end of such a chamber, particularly if the very fine dust at the end of the chamber is to be forced through a dust collecting device. At regular intervals in the expansion chamber, gates are placed to receive the gradings which will, of course, be of a size inversely proportional to the cross section at any point. These gates are usually held to place by a lever and weight. When sufficient material has collected in the pocket above the gate to more than counterbalance it, the gate will open and permit the grading to discharge. Gates of this kind are, of course,

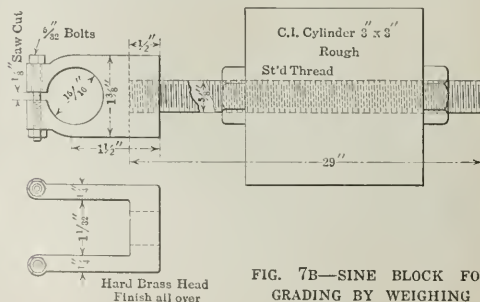


FIG. 7B—SINE BLOCK FOR GRADING BY WEIGHING

necessary to prevent the air from passing through the discharge passages, taking with it material which does not belong at this point.

Expansion chambers can be placed horizontally, on an inclination or vertically; in the last case consisting of a series of expansion chambers placed one above the other, the sizes increasing from top to bottom.

The vertical arrangement is the best from the theoretical point of view, but it has the disadvantage of requiring more head room than the other forms. With the vertical forms the air has the power to balance a grain of a particular size or weight, the balance being dependent upon the velocity, and this in turn upon the initial velocity created by the fan, and the area of the cross-section at the point of balance.

Grading by horizontal and inclined forms of chambers depends upon the transportive power of the air current, and the question as to whether a grain of a particular size will alight in the appropriate pocket depends not only on the transportive power of the current, but also the position of the grain in the current. If well above the discharge pocket into which it should discharge, it will fail to report in it and will be carried ahead. Also, if the grains which are reckoned too small to report in the pocket are in the current just above it, they will fall into it.

Air-grading is very little practiced to-day, for the settlement chambers required are very large as compared with settlement chambers for a heavier fluid such as water. If the material being graded permits of the use of water, this undoubtedly should be employed in preference to air. It is impossible to prevent strong cross-currents and eddies in the expansion chambers and this confuses the grading, making it quite markedly inferior.

A certain amount of fine dust is bound to cling to the walls at all points of the expansion chambers and this will contaminate the gradings.

There is no technology of this type of apparatus. In the vertical forms of apparatus, if the velocity of the air from point to point is known, as it can be, knowing the fan velocity discharge, it would be possible to calculate the size grain that the air current would balance. The pressures created by air velocities have only been calculated for large surfaces, and, as is well known, the smaller the surface the less does the unit pressure become.

In the inclined forms of chamber, the pressure of the air current is balanced against the inclined component of gravity less friction of the bottom of the chamber.

For horizontal expansion chambers of regular form, truncated pyramids or cones, the path of a particle in the feeding plane may be calculated theoretically from the following formula

$$y = \frac{x^2 A^2 g}{4 A_1^2 L V^2}$$

where A is the area of the small end of the chamber, A_1 the area of the large end, L the length of the chamber, V the velocity of the current in feet per second at the entry of the blast into the expansion chamber, and g the constant of acceleration.³ The axes of the curve are taken through the center of the particle just as it enters the expansion chamber, and, of course, values for y are negative and for x positive.

I have some information to the end that air-grading is used for separating chicken feathers into various sizes. In the dry process for mica, air-grading is still

used to some extent, but there are so many secrets in this industry that it is impossible to determine how the air-grading is done.

Grading by Projection

Some attempt has been made to grade material by the varying trajectory when thrown from the surface of an endless belt where it passes around a pulley. In this case, owing to the greater opposition of the air, the largest pieces should fall nearest to the pulley, with successively finer pieces as the distance from the pulley increases. If the particles are of different kinds of material and with different modes of fracturing, this mode of grading may offer means for separating the constituents by screening or other ways following the belt-grading. If the particles be of varying specific gravity the alighting position of particles of the same size will be modified to some extent by this difference, the heavier particle alighting somewhat closer to the pulley; but specific gravity differences will not affect the grading so much as differences in size or shape.

Professor C. F. Hirshfeld has experimented with this mode of grading in endeavoring to discover a means of separation for various constituents of a low-value ore which did not differ much from one another in point of specific gravity. It was found that very high belt-speed was necessary and this required that the apparatus be massive and have good foundations. Another difficulty encountered was with the differential crawl of the material on the belt under the high speed necessary. This was overcome by having two belts in contact with one another, both running in the same direction and with the same speed, the material being conveyed by the lower one and slippage being prevented by the upper. Both belts were run horizontally.

True Classification in Rising Currents of Water

Grading which is done by an uprising current of water or other liquid is called classification. In the ore-milling industry this mode of grading has some advantages over screens or other modes of grading in preparing material for certain kinds of separating machines. The technology of grading in rising currents is discussed at length in the text books on ore-dressing.⁴

Outside of ore-milling, grading by rising currents does not receive any extended use, for the work done is not sufficiently sharp for the majority of grading problems. The characteristic of any grading made by classification is the presence of grains whose size is well defined as to the upper limit, but the lower limit can scarcely be said to be defined at all. The majority of the grains are of sizes nearer to the upper limit than the lower; but in every classification there are grains of all sizes, from the largest which are rejected by the current in the grading next above any particular one in consideration, down to the very finest. When particles fall in water, beyond a very brief moment of acceleration the rate of fall is uniform, and depends upon the size of the grain—large grains falling faster than small—and on the specific gravity the greater the specific gravity the greater the rate of fall.

Formulas for rate of fall and their variation from experimental results will be found discussed at length in the authority which has been given. Theoretically, when the rising current just balances the velocity of any particular size and kind of grain, all particles of larger size should fall and smaller ones rise. In practice, the friction of the current on the sides of the enclosing hydraulic chamber, the deflections of the current caused

³The retardation in fall by air friction has been neglected and since the gradation of size depends on the large grains falling faster, a factor depending upon size would have to be applied to the formula to obtain the actual path.

⁴'Richards' Ore Dressing will be found to be the best authority to consult, the author having been for a long period an authority on this branch of the subject.

by the falling grains and certain interstitial actions which occur between the larger grains, cause downward forces tending to carry down and deliver with a particular grading small particles which do not belong to it.

In addition to grading by rising currents there is the form of water classification which is practiced to some extent by direct settlement for varying periods of time. In the abrasive industry there are classification grades made by the settlement of the material in cones of increasing diameter. Following the grading done in this way, a barrel is filled with the overflow of the largest classification cone and the material in the barrel is allowed to settle for a definite length of time. Material which has failed to settle in this period is siphoned off into a second barrel where it is allowed to settle for a greater length of time, when the siphoning operation is again undertaken, and so on, the successive operations yielding any desired number of grades and of any desired fineness.

Methods of Grading Very Fine Materials

For grading analyses below 200-mesh, a settlement-and-siphon method is used to some extent, the results being reported as such and such percentages for such and such times.

A better mode of carrying the sizing test below the limit of screens is to take a small portion of the minus 200-mesh product and measure it under the microscope, the measuring device being a carefully ruled grid on a glass plate holding the particle to be measured.

The most generally accepted set of testing screens have the apertures diminishing in size by reducing the area of the aperture a half from screen to screen. If the glass plate be engraved with squares which diminish in the same way beginning with half the area of the 200-mesh screen, the standard width of opening of which is 0.0029 in., a count may be made of the grains which are larger than the different size squares, the various groups of oversized grains being successively removed from the sample after measuring. This method is limited by the magnification of the microscope and the skill of the investigator.

In calculating the weight of a particular grading by this method, the average linear dimension of the squares (half the sum of the side of square on which the grain is being tested and the side of the next largest square) is cubed and this factor multiplied by number of grains to obtain weight and percentage by weight. This mode of computation is, of course, only approximate and subject to much error.

The direct weighing of the particles entails great care and skill, and the difficulties of obtaining the weights and percentages by direct weighing increases as the size diminishes. Increased accuracy might result if the microscopical apparatus were mounted with a gage for taking the depth of the grain.

(To be continued)

Denver, Col.

Steel Plant to Have Entire Electrical Equipment.—The Inland Steel Company has placed an order with the Westinghouse Electric & Manufacturing Company, of East Pittsburgh, for the complete electrical equipment of its new plant at Indiana Harbor, Ind. The order represents an expenditure of over one million dollars and when completed the company will have what is said to be the largest electrically-driven steel plant in the world.

Aluminum in 1915.—The production of aluminum in 1915 is estimated by several authorities to be close to 80,000,000 lb. This is a record of achievement and compares with production in 1914 estimated at 45,000,000 lb.

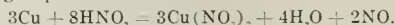
Blast Furnace Smelting of Cyanide Precipitate

BY REGIS CHAUVENET

It is not necessary to review all of the methods which have been used or proposed for the treatment of the so-called cyanide "precipitate." These methods, to use a rather Hibernian expression include the case where there is no precipitate to treat, as for example the re-gaining of the gold without the use of either zinc or carbon.

Originally, the most obvious method was the first attempted. Nothing was simpler, on paper, than the solution of the zinc and all other impurities in some appropriate solvent, leaving the gold behind. It was discovered before long that there were many cases in which this was quite impracticable; and, naturally, they were so in the proportion in which the impurities were themselves insoluble or difficultly soluble in the menstruum.

Nitric acid is out of the question to begin with, on account of its expense. Take for example, copper, whose average equation of solution is:



We destroy 2 $\frac{3}{4}$ lb. of actual nitric acid for each pound of metal, approximately the same for zinc, though considerably less for lead. Indeed, the cases quite other than the one under consideration, in which nitric acid has been proposed, and abandoned on account of its cost, are numerous in the annals of hydro-metallurgy.

As for sulphuric acid, it will not dissolve lead except under "impossible" conditions. It takes up copper only by application of a mixture of air and steam. This has been used in the purification of silver, but as the question is almost always complicated by the presence of other impurities, sulphuric acid for the removal of copper at the same time with the zinc, is of a class of problems more curious than practical.

However, as is well known, sulphuric acid has been used in those cases where the total copper *plus* total lead are so low that the precipitate is substantially nothing but gold and zinc.

Fire Methods of Refining Precipitate

Other curious methods have been proposed, some of them heralded as the "long-looked-for-come-at-last." This brief discussion of wet treatments of the precipitate is intended merely to introduce the subject of fluxing, i.e., to indicate that there are cases in which some form of dry treatment, more or less approximating actual smelting operations, is imperative. There remains, to be sure, electrolytic separation, but here again conditions often prohibit.

We are reduced to three furnace methods:

- (1) Direct cupellation.
- (2) Reverberatory hearth.
- (3) Blast-furnace.

For purposes of this discussion the first method is rejected on account of high copper.

We must here quote rather extensively from the long and highly informative articles by J. W. Hutchinson, on the Goldfield Consolidated mill, where the operations to be presently described were initiated. We condense the description of the original method of smelting, but it is necessary to indicate the difficulties of the earlier trials in order to appreciate the improvement introduced by the full smelting method.

The melting-room as originally designed, contained a double-muffle drying-furnace and four Faber du Faur tilting furnaces for treating the precipitate. The proc-

¹Min. & Sci. Press, May-June, 1911. Reproduced in "Cyanide Practice, 1910-1913," Von Bernewitz.

ess consisted of nitre-roasting the precipitate, with subsequent melting in the tilting furnaces. Bullion from this method averaged 250 fine in gold and silver.

Later, acid-treating tanks were put in which materially reduced the amount of precipitate to be melted, and by addition of pyritic concentrate, enough copper and lead were converted to matte to raise the grade of the bullion to 425 gold and silver. (The analysis here introduced is omitted, but the bullion shows over 40 per cent of copper, 13 per cent of lead and $3\frac{1}{2}$ per cent of zinc.)

No wonder that, to quote again from the article, "The process was decidedly unsatisfactory." Much work was done to ascertain whether some wet method could not be adopted. Electrolytic parting was suggested and abandoned. Another method which included matting away of the copper, gave a lead bullion high in gold and silver.

It had been about decided to try reverberatory smelting, first briquetting the precipitate with litharge and fluxing on a reverberatory hearth. Mr. Hutchinson here gives Mr. Henry Hansen of Blair, Nev., credit for the suggestion of blast-furnace treatment. It had been tried on a small scale at the Pittsburgh Silver Peak Company.

Blast-Furnace Smelting of Cupriferous Precipitate

The new departure consists in nothing less than the actual smelting of the precipitate on a lead basis, in a small furnace constructed in miniature exactly like a lead-smelting furnace. "Smelting precipitate containing 40 per cent copper on a lead basis did not sound very attractive as blast-furnace work at first," but it was soon found that it could be efficiently done.

Briquettes were made consisting of:

Dry precipitate	100 parts
Litharge	100 to 125 parts
Blanket concentrate	60 to 75 parts

This "concentrate" held 35 per cent silica and 30 per cent of sulphur. Subsequently the proportion of litharge used in the briquettes was made still higher.

The precipitates of several years had the following average percentage analysis:

	1911	1910	1909
Au	21.50	8.75	13.43
Ag	3.00	1.14	2.13
Cu	39.80	21.59	22.85
Pb	4.50	28.58	6.86
Zn	15.50	12.57	32.50

There is variation enough here to bring much "grief" to the experimenters. Nevertheless success eventually crowned their efforts.

It is evident that if the precipitate is to be treated in a blast furnace "on a lead basis," there may be two cases, viz.: matte or no matte. With high copper the only practicable scheme is the formation of a matte, and this will perhaps inevitably entrain both lead and zinc. In the absence of copper this necessity disappears. Hence came the addition of concentrate to the charge, which in the case of the high copper precipitate was left raw for the utilization of its sulphur, but when copper was practically absent it was added more for the sake of its silica (for slag formation) and its incidental value. In this case roasted concentrate was used.

In both cases the addition of iron oxide is almost a *sine qua non*, since we are to depend mainly upon the reduction of the lead for the collection of the gold and silver, and the carrying of the zinc into a slag, which would hardly possess the requisite fluidity unless high in iron.

Effect of Zinc in Slags

The composition of a slag which is to carry zinc oxide, is too well known to require much discussion. It is true

that we are not trying to dictate composition, but rather method of computation of this slag, but some consideration of its essential qualities cannot be wholly omitted. Lime and zinc oxide seem to be natural enemies, so far as slagging together is concerned. It has often been given as a rule, that when lime rises into the twenties in a slag, zinc acts more and more as a stiffener, and it is said that when lime reaches 28 per cent, zinc oxide refuses to enter the slag at all. While we are not responsible for these figures, there is no doubt that zinc cannot be slagged off in smelting unless high iron is present. Iron is added in such cases to such an extent as to lessen materially the total percentage of silica.

The blast furnaces adopted at Goldfield are of the cylindrical type, 20 in. in diameter at the tuyere line, with riveted steel jackets. In blowing in the wood fire is maintained until crucible and lead-well are cherry red. Coke is added and the fire urged to white heat. Five hundred pounds of lead is fed in to fill the crucible. Blank charges of coke and slag are fed until the furnace is half full. Then comes the regular charge, consisting of:

Briquettes	100
Old slag	40
Borax	10
Cupel bottoms	51
Iron (oxidized)	2
Coke	25

So far, the old practice. The lead bullion contained under this method approximately 20 per cent gold and silver, and 1 per cent copper. The matte from these runs contained average of 20 per cent lead, 50 oz. gold and 200 oz. silver per ton. This accumulates until sufficient matte is on hand to be separately run.

TABLE I

Analyses of all the constituents of the charges, except iron oxide which is nearly pure Fe_2O_3 obtained by dead-roasting pyrite. Gold and silver contents of Consolidated and Aurora precipitates are given in ounces per ton; gold value of raw concentrate in dollars. All other figures are percentages.

	Consolidated Ppt.	Aurora Ppt.	Raw Concentrate	Roasted Concentrate	Selby Slag	Remarks
Au	3470	2578	\$50	....	....	
Ag	808	2229	....	....	....	
Cu	22.0	0.2	0.5	0.6	....	
Zn	22.0	40.8	....	....	....	{ 40.8 called
Fe	....	0.5	20.0	22.2	40.0	{ 41 in problem
				(40 FeO)	(51.4 FeO)	
CaO	5.5	7.2	....	....	20.0	
SiO ₂	....	11.6	50.0	54.6	30.0	{ 55 in problem
S	....	....	19.0	1.0	....	{ 54.6 called

Mr. Eugene G. Snedaker has kindly furnished us with analyses of the various products which enter into the problem. As to the slag produced, we are not able to pronounce upon it, as it shows a summation of less than 77 per cent, viz.:

	Per Cent
Insoluble	24.8
FeO	26.3
CaO	5.5
ZnO	12.3
Pb	6.5
Cu	1.3

"Soluble silicates and borates undetermined; gold, 1.2 oz. per ton."

This, inferentially, leaves us with the astonishing proposition that $22\frac{1}{2}$ per cent of the slag consisted of bases other than those named. Here, however, we drop discussion of the practice, as it is mainly our intention to explain the computation of a rational flux addition to the briquettes.

Turning now to the analyses of precipitates, concentrates and Selby slag given in Table I, it appears that we have to consider both high and low copper, also both raw and roasted concentrate. As it is obvious that one of these cases demands a matte and the other none, we take them up as two separate problems.

Problem I. No Matte Formed in Smelting

Assuming then, that in any given charge or campaign we are to use but one of the given precipitates, we start with the Aurora.

Theory calls for the addition of about 150 lb. of litharge to 100 lb. of precipitate, to supply oxygen for the reaction:



In 100 lb. of precipitate (zinc = 41 per cent) the atomic weight proportion is:

$$65 : 16 = 41 : 10.10$$



And for litharge:

$$223 : 16 = 150 : 10.76$$



The margin is small, being in fact 10.76 minus 10.10, or 2/3 lb. for oxygen. Probably the addition of a little more litharge would become the practice.

Leave out of all account, in slag calculation, the gold and silver. The reduced lead, *plus* that with which you start in the crucible should take care of the precious metals. Some lead will in all probability get into the slag. With it, possibly some gold and silver. As the slag is to be re-treated this is not prohibitory.

We now use the "representative" method of slag computation already illustrated several times in this journal.²

We enter our calculation with 51 lb. of zinc and 7 lb. of lime, each of these from the 100 lb. of Aurora precipitate. We are figuring for a slag, and we may leave matte out of the reckoning, as we have but 1 per cent of sulphur in the roasted concentrate. This trifle of matte will be drawn off with the slag and will go into the retreatment of the latter.

What slag shall we figure for? I adopt the purely arbitrary figures $\text{SiO}_2 = 30$ per cent, $\text{FeO} = 50$ per cent and $\text{ZnO} = 20$ per cent. The lime is to be *included* in the figure for zinc oxide. Iron oxide (Fe_2O_3) has to be provided as flux, and it appears from the records of the company that a roasted pyrite furnished this essential constituent of the charge.

As usual assume 100 lb. as basis for your calculation, i.e., 100 lb. of precipitate. Call your concentrate 100x, and your iron oxide 100y.

Get expressions for total silica, FeO and ZnO (include CaO in the latter).

Remember that the Fe_2O_3 reduces in slagging to FeO, whose weight is exactly 90 per cent of the higher oxide. Expressions for all the constituents will be as follows:

	SiO_2	ZnO	FeO
From precipitate	12	58 (c)	... (a)
From concentrate	55x	..	40x (b)
From Fe_2O_3	..	..	90y
Totals	12 + 55x	58	40x + 90y

(a) Neglect the 0.5 per cent iron in the precipitate. (b) The 32.2 per cent Fe in the concentrate is equivalent to 40 per cent FeO. (c) The 41 per cent Zn is equivalent to 51 per cent ZnO; this added to the 7 per cent CaO makes 58 per cent of the two oxides.

Now by the slag conditions of the problem ($\text{SiO}_2 = 30$, $\text{FeO} = 50$ and $\text{ZnO} = 20$), we have $5 \times \text{SiO}_2 = 3 \times \text{FeO}$, that is:

$$60 + 275x = 120x + 270y \quad (1)$$

Also, $2 \times \text{SiO}_2 = 3 \times \text{ZnO}$, that is:

$$24 + 110x = 174 \quad (2)$$

These two equations which are very quickly solved, give us $x = 1.3636$ and $y = 1.005$ or $100x = 136.36$ and $100y = 100.5$. That is: for each 100 lb. of precipitate add 136.36 lb. concentrate and 100.5 lb. of iron oxide.

²Calculation of Furnace Charges, Regis Chauvenet, this journal, January, February, March, April and June, 1912.

PROOF.—Take the quantities indicated, and calculate from the analyses the weights of each constituent added. If these come out in the proportions required, i.e., 30 : 50 : 20, the proof is perfect.

	SiO_2	FeO	ZnO
Precipitate	12	..	58
Concentrate	75	54.55	..
Iron oxide	..	90.45	..
	87	145.00	58

The sum is 290 lb. slag, and calculating the percentage of each constituent, we find that:

$$87 : 145 : 58 = 30 : 50 : 20$$

exactly as required by conditions.

The slag then, irrespective of the old slag addition to be presently mentioned, will have the composition, $\text{SiO}_2 = 30$ per cent, $\text{FeO} = 50$ per cent and $\text{ZnO} + \text{CaO} = 20$ per cent.

Function of Old Slag in Charge

In all smelting operations of this general description, old slag is added to each charge, to facilitate melting. In the description of the former practice it is stated that the old slag from the operation itself was added, though it became so "zinky" that it had to be rejected after a while. Instead of this addition, "Selby" slag is substituted. It is not usual, nor is it necessary, to work the analyses of this addition into the general computation. The old slag, because it does not have to go through the formation period, aids the melting of the charge. Its composition as shown ($\text{SiO}_2 = 30$ per cent, $\text{FeO} = 50$ per cent (about), and $\text{CaO} = 20$ per cent), is singularly near the desired final outcome. This addition of a standard slag from lead practice, is greatly to be preferred to the return of the zinky slag from the smelting of the precipitate. Incidentally, composition is bettered, because of the lowering of the percentage of zinc. It will always be a problem more or less difficult to obtain a slag which, in carrying off all of the zinc, will at the same time be fluid enough for easy handling.

It was then, not without a realization of these troublesome elements that the management adopted "Selby" slag as the regular addition to their charge.

In the computation to follow all bases other than FeO are set at 20 per cent, zinc oxide being the chief one.

Here let us say, once for all, that we wish to illustrate a method of computation, and are not dictating the composition of a slag obtained under conditions unfamiliar to us. Whether the particular proportions are the best does not cut much figure, since the method is perfectly general. Thus, if a slag proves to be too pasty because it is too zinky, lower its zinc contents and recompute the charge. In short the *method* is mathematical, not physical. We apply our knowledge of slags, of course. We remember that high lime and zinc are incompatible, and that multiplicity of bases helps fluidity, and we bring to our aid whatever local experience has indicated. This experience having given us a preferential composition, all our method does for us is to give an easy solution for compounding the charge for production of the desired result.

Problem II: Matte Formed in Smelting

We now take up the "Consolidated" precipitate, which, being high in copper, is to be smelted with raw sulphide concentrate.

We must first "take out" the matte from the raw concentrate, i.e., calculate out its iron against its sulphur. The iron is 20 per cent in the raw concentrate. Apportion it on the formula FeS to the sulphur:

$$56 : 32 = 20 : 11.4$$

$$\text{Fe} \quad \text{S} \quad \text{Fe} \quad \text{S}$$

That is, sulphur required for iron in matte is 11.4 per cent. We have 19 per cent sulphur in the concentrate, which minus the 11.4 per cent required as above leaves us 7.6 per cent which is to be adjusted to the copper of the precipitate. This sulphur may be adjusted thus; the formula of the copper sulphide in the matte is assumed as Cu_2S , which contains practically exactly four times as much copper as sulphur. That is, in 100 lb. precipitate we must add available sulphur weighing one-fourth of our copper content of 22 lb. One-fourth of 22 is 5.5. We have then simply to answer the question, "How many pounds of concentrate with 7.6 per cent available sulphur will yield 5.5 lb. of same?" That is, merely,

$$7.6 : 100 = 5.5 : 72.4.$$

That is, 72.4 lb. of the raw concentrate will supply sulphur enough both for its own iron and for the 22 per cent copper of the precipitate.

Since we have 50 per cent silica in the raw concentrate, 72.4 lb. contain 36.2 lb. silica.

In 100 lb. precipitate we have

22	zinc	=	27.4	ZnO
5.5	CaO	=	5.5	CaO
Say..... 33 lb. base				

We want, say 50 per cent FeO in the slag. Now since we have 36 lb. SiO_2 and 33 lb. base, the two making 69 lb., the other half of the slag, FeO, must also be 69 lb. This weight of FeO will be yielded by 76.6 lb. of the ferric oxide, Fe_2O_3 .

By pounds the slag will be:

SiO_2	.....	36
Base	.....	33
FeO	.....	69
Total	.....	138 lb.

By percentage composition this reduces to:

SiO_2	.....	26 per cent
Base	.....	24 per cent
FeO	.....	50 per cent

The charge then, irrespective of coke and "Selby" slag, will be:

Precipitate	.....	100.0 lb.
Concentrate	.....	72.4 lb.
Fe_2O_3	.....	76.6 lb.

This method of computation assumes that we must apportion the iron in the concentrate to its sulphur, and then compute the whole of the added iron oxide into slag. This is as good a way as any, but, in fact, there are half a dozen ways, more or less conventional, of adjusting the bases to sulphur and silica.

Impossible to Form Both Slag and Matte of Assigned Composition

In review it must be noted that we have here conditions whose simultaneous fulfillment is impossible. For it will not be possible to compose a charge so that we shall have at once a slag and a matte of assigned composition. In other words we have two incompatible conditions, which could be simultaneously satisfied only by a fairly miraculous coincidence.

Having, however, secured an approximation to the desired slag, it would be easy to get the exact requirement, provided we had perfectly pure material, i.e., material containing only silica, or only base. As to what the ideal slag for the operation would be, could be determined only by experience, and a good deal of it.

Let us exemplify by two assumptions: (1) we have the "Selby" slag, and (2) we have pure SiO_2 and pure Fe_2O_3 . Now we can never get a precise solution by the addition of another slag, for the addition of one element enforces the addition of others in set ratio, i.e., only by a miracle could we get the ideal.

With separate pure material on the other hand we can always secure any desired slag. This we shall illustrate in conclusion of the article. We should add that as a mathematical principle, we may always secure any required slag provided there are but three constituents in the aggregate composition.

First. Suppose we use "Selby" slag to assist in slag formation. This, by the way, is supposing what is actually done in every charge.

As sent to us the analysis figures out 101 per cent, so we knock off 1 per cent and call the "Selby" slag:

SiO_2	.....	30 per cent
FeO	.....	50 per cent
Base	.....	20 per cent
Total	.....	100 per cent

Add 100 lb. of this slag to our already deduced charge, we shall have:

SiO_2	=	36 + 30	=	66 lb.
Base	=	33 + 20	=	53 lb.
FeO	=	69 + 50	=	119 lb.
Total	.....			238 lb.

The composition by percentage is very easily figured out, giving:

SiO_2	.....	27.7 per cent
Base	.....	22.3 per cent
FeO	.....	50.0 per cent
Total	.....	100.0 per cent

We see that we have not made any great change in the composition. The "Selby" assists in formation but not in proportions, i.e., not materially.

It is quite otherwise when we come to additions of Fe_2O_3 and SiO_2 . Take the original charge and add as shown. We are trying to secure as nearly as possible the original requirement, and to do so we add *such weights* of SiO_2 and FeO as to bring their totals to the ratio of three to five. This explains the apparently arbitrary assumption of 24 and 31 as the additions of SiO_2 and FeO. To get 31 lb. FeO we add 34.4 lb. Fe_2O_3 .

Pounds in slag:

SiO_2	36 + 24 added making	60 SiO_2
Base	33 + 0 added making	33 Base
FeO	69 + 31 added making	100 FeO

Reduce the above mixture to analysis:

SiO_2	.....	31.1 per cent
Base	.....	17.1 per cent
FeO	.....	51.8 per cent
Total	.....	100.0 per cent

We recognize this at once as a fusible slag. It might be slightly improved by dropping silica a trifle. However, with its high iron and its bases (zinc and lime) cut down to a total of 17 we shall hardly "freeze."

Various changes may be introduced into the composition by prior calculation; the possible variants being infinite, we leave them to the student's devices. We shall give a single case. Suppose that to each 100-lb. slag (26:50:24) we are to add SiO_2 and Fe_2O_3 so as to bring it to (30:50:20). We may do so without equation, thus: The base equals 24 per cent, which by the proposed change is to become 20 per cent. Then the weight must be made 120 of which 60 (50 per cent) must be FeO; therefore, add 10 FeO (11.1 Fe_2O_3) and 10 SiO_2 . Then we have:

SiO_2	=	36
FeO	=	60
Base	=	24
Total	.....	120

and the required percentages are obtained, i.e., 30:50:20. Similarly any desired change can be readily made.

Denver, Col.

Recent Chemical and Metallurgical Patents

Electric Furnaces

Electric Furnace.—A pinch furnace containing several compartments is patented by CARL HERING of Philadelphia, Pa. The principle of the pinch furnace was described by Dr. Hering in this journal, Vol. IX, 1911, pages 277 and 371. The present furnace is designed primarily for melting material of low resistance, such as copper, silver, gold, or alloys. The compartments are connected with each other by channels and a circulation through the

compartments is created by the pinch effect. A two-compartment furnace is shown in plan and cross-section in Fig. 1. The cross-section is taken on the line XX of the plan view. The furnace proper, of refractory material, is shown at W. The two compartments, H, H', are filled with the material to be melted. The electrodes EE' are connected to the bottom of the compartments in contact with the molten material as shown. The channels R'R' meet at P and communicate with the common pouring spout S. By using more compartments, such as three or five, or more, three-phase alternating currents may be used. The advantages claimed for this type of furnace are that it permits of the use of relatively higher voltages, lessening the electrode losses, and also permits of the use of different slags in the different compartments with correspondingly different refractory linings. In refining steel, an acid slag may be used in one compartment, while a basic slag is used in another, thus avoiding the need of changing slags. By using a number of compartments, cold metal or raw material can be introduced in one compartment for melting, while another compartment may be used for refining the slag or other treatment, thus making a continuous process. The resistor channels may be made of other shapes, such as conical for the purpose of making the flow stronger in one direction than in another (1,162,773, Dec. 7, 1915).

Electric Furnace.—A patent of ALEX DOW of Detroit, Mich., refers to electric furnaces using a granular resistor, such as carbon, as heating element, the object to be treated being placed above and heated by radiation from below. As the radiating surface of the resistor assumes a temperature slightly lower than the rest of the resistor, the current is caused to be deflected downward on account of the increase in resistivity of carbon with decrease of temperature. To overcome this defect in furnaces of this type, Mr. Dow places a series of bars of magnetic material (iron) below the granular resistor and at right angles to the direction of the current. These bars become magnetized and deflect the current upward toward the working zone of the furnace where the heat is needed (1,164,634, Nov. 23, 1915).

Electric Furnace for Producing Aluminium Nitrides.—A furnace for manufacturing aluminium nitride from bauxite and coal based on the original intermittent electric furnace process of Thomas L. Wilson, patented in England in 1895, is patented by GEORGE COUTAGNE of Lyon, France. Several modifications have been made in lower electrode and in the furnace casing. A cross-section of the furnace is shown in Fig. 2. The upper electrode H is a movable solid cylinder. The lower electrode is made of a large tube A of agglomerated coal. Between A and the shell of the furnace refractory material C is placed. Within A is a column of coke B. The nitrogen-containing gas, such as generator gas, is introduced through D into the annular space E under pressure, and is forced up through the furnace. No refractory lining is used on the shell above C, and all openings K at the top are made gas tight. In starting the furnace the upper electrode is lowered until it touches B. The coke is allowed to heat up for

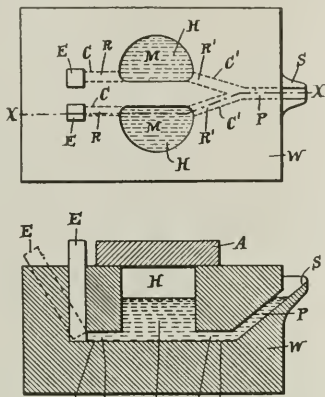


FIG. 1—PINCH FURNACE

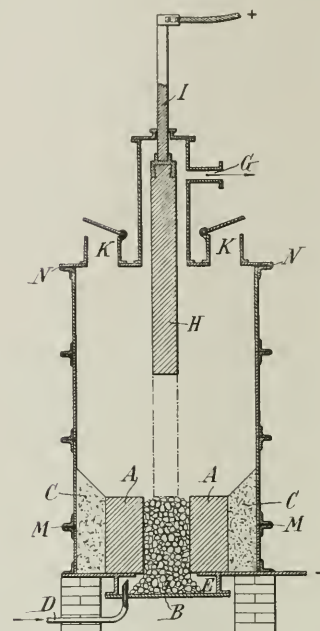


FIG. 2—ALUMINIUM NITRIDE FURNACE

awhile, then the mixture of bauxite and coal is gradually added through openings K, and the flow of generator gas is started. The work of the current is localized toward the center of the furnace and the outer portions of the charge adjacent the iron casing will not conduct the current so much. This permits the use of the unlined casing above mentioned. An operation lasts several days, and when finished the whole furnace is filled. The aluminium nitride is formed in a cake at the center of the furnace when cooled down, and is surrounded by an agglomerated mass of coal and bauxite at the periphery. The nitride is subjected to a high temperature during the operation, and it is stated that the retrogression studied by Fraenkel (*Zeit. für Electrochemie*, April 15, 1913) at 1500-1600 deg. does not take place (1,158,899, Nov. 2, 1915).

Electric Furnace.—An electric furnace which utilizes the heating effect of eddy currents is patented by Sigmund Guggenheim of Berlin-Wilmersdorf, Germany. Three-phase currents are used, which is claimed to make the melting operation more economical by providing a greater concentration of magnetic lines in the body to be heated. The furnace consists of a receptacle containing the material to be heated, placed in the air gap between the poles of three magnets. When these magnets are wound so that their current supply is in the same sense, a large proportion of the magnetic lines of force will not pass entirely through the material to be heated, but will be diverted from one pole to the next adjacent one. If, however, the winding

of the middle magnet be made such that the current is in the opposite sense to the other two, then a much larger number of lines of magnetic flux will go through the material to be heated. This unequal displacement of the magnetic phases is the feature of the furnace. (1,157,691, Oct. 26, 1915.)

Cementing Carbon Articles and Electrodes.—In baking carbon articles a porous product is apt to result due to the escape of volatile matter while baking. This is objectionable as it raises the resistance and in the case of carbon anodes the deterioration is hastened. A process for making the articles more dense by simultaneous heating and compression is patented by JOHN W. BROWN of Lakewood, Ohio, (assigned to National Carbon Company, Cleveland, Ohio). The articles are first impregnated with a tarry binder and then placed between plates for compressing and each end connected to electric terminals. An average current density of 1000 amp. per square inch is used. After the articles have heated up the material becomes semi-plastic and flows, cementing the particles together. The pressure does not have to be applied at the start but may be omitted until the material becomes heated. In the apparatus described the pressure is applied by a hand wheel. (1,158,171, Oct. 26, 1915.)

Electrolytic Processes

Diaphragm for Alkali Chloride Electrolysis.—In order to make it possible to use high currents with a vertical diaphragm cell a patent of ADOLF CLEMM of Mannheim, Germany, proposes to use a compound diaphragm, i.e. a diaphragm made up on one side of a substance which is not attacked by chlorine and on the other side of a substance not attacked by alkali hydroxide. The construction of this diaphragm is shown in Fig. 3. A powdered material *b*, such as barium sulphate, not attacked by chlorine, hydrochloric acid, or alkali, is supported on the cathode side by a material *a*, such as asbestos, while strips *c*, of glass, ebonite, or stoneware are arranged on the anode side. The diaphragm is claimed to be very durable. (1,160,847, Nov. 16, 1915.)

Acetic Acid from Acetylene by Electrolysis.—A process for producing acetic acid from acetylene by electrolysis is patented by CHRISTIAN HANSEN and ANTON WEINDEL of Leverkusen, Germany (assigned to Synthetic Patents Company, Inc., New York City). "The anode space of an electrolyzing chamber provided with a diaphragm of clay and an anode of platinum is charged with sulphuric acid (30 per cent) and 1 to 2 per cent of mercuric oxide, calculated according to the weight of the anodic liquid, while the cathode formed of lead or copper is also immersed in sulphuric acid (30 per cent). Acetylene is then introduced into the anode space, allowing the electric current to pass through and stirring at the same time. In this process 48.5 parts of acetylene are used every hour for every 100 amp. of current. The tension of the bath at a current density of 0.25 to 0.75 amp. per square decimeter of anode surface is 3 to 4.5 volts, and the temperature of the electrolyte is kept at 30-40 deg. C. A good yield of acetic acid is obtained" (1,159,376, Nov. 9, 1915).

Electro-Osmosis

Electro-Osmotic Filter Press.—In removing water from peat, clay, kaolin and like substances, consider-

able pressure has been heretofore required in filter presses as the fineness of the solid particles in suspension decreased, but for colloidal matter these presses could not be used. A press in which osmosis is taken advantage of has been patented by BOTHO SCHWERN of Frankfurt-on-the-Main, Germany, (assigned to Gesellschaft für Elektro-Osmose M. B. H. of the same place). In this press the material to be treated is run into the filter press chamber as into any ordinary press. But the two walls which hold this material are made electrodes of opposite polarity. They are perforated and a filter cloth placed over them. By using electricity and pressure, combined the water may then be extracted running into the adjacent empty chambers and passing out. The form of the press is about the same as an ordinary filter press. The electrodes are made of hard lead and the pressure required will be very slight, and under certain conditions suction may be used. In removing water from peat, clay or chalk by this method it has been found that ferric hydroxide separates out at the electrode toward which the water migrates, usually the cathode, and gradually chokes the press. This may be overcome by reversing the current occasionally. (1,156,715, Oct. 12, 1915.)

Aluminium

Treating Aluminium Scrap.—A process of treating aluminium screenings, dross or slag from aluminium casting operations for the recovery of aluminium and other metals is patented by JAMES WRIGHT LAWRIE of Aurora, Ill. The scrap which may contain iron, copper, zinc or other metals is screened through a fine screen and slowly fed into a closed tank provided with stirring mechanism, outlets for gases, and means of applying external heat and pressure. The tank contains a caustic soda solution, which dissolves the aluminium and alumina. Alumina has a negative heat of solution in caustic soda, but the necessary heat is furnished by the aluminium and other substances in the material and by applying external heat. A charge consists of 3000 lb. of material and 2500 lb. of caustic soda in 5000 lb. of water constitutes the solvent. The material is fed in fast enough to furnish enough heat for solution and not too fast to cause foaming or violent boiling over. The external heat is applied at first after the heat of the reaction has been sufficiently used up, with at first only a slight pressure on the solution. Later the pressure is elevated and the solution of the alumina continued. The charge is filtered after dissolving and the residue treated for the recovery of zinc, copper and other metals. The aluminate solution is precipitated as hydrate of alumina, filtered and the solution used again. (1,156,606, Oct. 12, 1915.)

Boron

Stable Boron Nitride.—The boron nitride produced according to most processes is not chemically stable, being slowly decomposed by hot water, forming boric anhydride and ammonia, and is also liable to oxidation. A process for making a stable product is patented by George Weintraub of Lynn, Mass., (assigned to General Electric Company). He discovered that when unstable boron nitride is heated to a temperature of 2000 deg. C. or higher, a stable product results which can be heated in boiling water without any noticeable decomposition, and is less easily oxidized. The process may be carried out in an electric resistance furnace, and any unstable boron nitride may be used as a raw material. About 20 per cent of a boron compound such as borax or boric anhydride is added to prevent any oxidation of the boron nitride. The heating is continued until no more fumes are given off. The time is comparatively

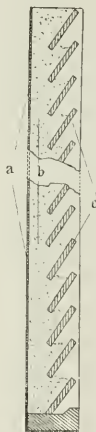


FIG. 3—COMPOUND DIAPHRAGM

short depending on the quantity used. (1,157,271, Oct. 19, 1915.)

Alloys

Hard Alloys of Lead and Alkaline Earth Metals.—In a number of patents granted to FRANCIS C. FRARY of Minneapolis, and STERLING N. TEMPLE of St. Paul, Minn., the inventors describe alloys of lead with calcium, magnesium, strontium or barium, or all together, and with or without small quantities of copper and aluminium. It is claimed for these alloys that they excel antimonial lead in hardness and toughness, and that they may be successfully used for such purposes as type metal, or wherever an alloy is desired for molding purposes. As the metals added to the lead are used in small quantities compared with the amount of antimony used in hard lead, the new alloys are proportionately less expensive than antimony lead, particularly under conditions when antimony is at an excessively high price. (1,158,671-2-3-4-5, Nov. 2, 1915.)

Iron and Steel

Charge-Car for Sintering Machine.—In sintering fine ore in pans it has been customary heretofore to provide a removable cover with burner mechanism, but without mechanical means for quickly and easily handling the cover; also the charging and leveling of the pans has frequently been done manually. According to the details of a patented charging car designed by Messrs. FRANK D. CARNEY and RICHARD V. MCKAY, of Steelton, Pa., mechanism is provided for raising or lowering the pan cover when the car has been run over the pan. The cover is provided with a drop bottom which carries a sufficient charge to fill the pan when dumped, and the bottom also acts as a leveling means for leveling the charge. The car carries an electric motor which actuates the mechanism as well as tanks for oil and compressed air and means for supplying the air tank with air at suitable pressure. These tanks supply fuel and air to the burner, which is on a level with the dumping bottom. A feature of the device is the delivery to the pan of a charge of uniform compactness, resulting in a reduction of the amount of fine, unsintered material remaining after the operation. (1,158,982, Nov. 2, 1915.)

Briquetting Process.—A process for making briquets from iron ore, flue dust, pyrites cinders, etc., for smelting is patented by Mr. DANDRIDGE H. BIBB of New York City (assigned to the Continental Process Corporation of Briarcliff Village, N. Y.). In the process the binder used is pyroligneous tar obtained from wood distillation. In briquetting flue dust it has been found that from 6 to 8 per cent by weight of pyroligneous tar will give a good briquet. The tar is first heated to the viscosity of a heavy mineral oil and then mixed with the granular material in any suitable apparatus. The mixture is then pressed into briquets and heated for ten to fifteen minutes to 250 to 300 deg. C. It is claimed that no disagreeable fumes will result. Another patent of the same inventor proposes to use as a binder the waste liquor obtained in the sulphite process of paper making. This liquor is evaporated to 30 or 32 deg. Baumé and mixed as above and the briquets pressed and heated for about twenty minutes to 300 deg. C. This treatment is claimed to give a water-proof, strong and compact briquet and to overcome all the previous difficulties experienced in using waste sulphite liquor as a binder. Another patent proposes to use as binder the waste sulphite liquor from the manufacture of chemical wood pulp. This binder is used the same as those mentioned above. Still another patent proposes to evaporate the waste sulphite liquor from paper making until a hard soluble pitch-like residue is obtained. This is

pulverized, a solution made of it and mixed with the material to be briquetted. The treatment from then on is the same as in the preceding patents. (In the order mentioned the patents are 1,158,363-4-5-6, Oct. 26, 1915.)

Gold and Silver

Slime Filter, and Method of Forming and Washing Solid Cakes.—In the ordinary process of filtering ore slime for the recovery of valuable solution, it is customary to use vacuum filter leaves on which a cake will be formed. The leaves are spaced apart and the cake formed on any leaf is not formed thick enough to come in contact with the cake on an adjacent leaf. These leaves may be inclosed in a drum into which the material to be filtered may be forced, and the process of filtration caused to proceed by pressure. In patents granted to DAVID J. KELLY of Salt Lake City, Utah, the inventor describes a method of forming "solid cakes," that is, cakes which are continuous between adjacent filter leaves. He also discloses his method for effectively washing such cakes. His filtering apparatus consists of leaves within a drum, with suitable connections through the container for the withdrawal of the filtrate. These connections are combined in a manifold pipe with necessary valves for controlling the flow of solution. In operation, the ore slime is forced into the drum and the separation of liquid and solid takes place under pressure, the liquid issuing from the drum and the solid forming a cake on the filter leaves. Filtration is continued until a solid cake is formed between filter leaves. In order to wash such a cake, valves are so arranged that water can be forced into alternate leaves, whereupon it passes out of these leaves through the cakes on either side and into the intermediate leaves from which it again issues from the drum. When the cakes have been sufficiently washed they are discharged by opening one end of the drum and running the leaves out on a track. The leaves may be flexibly mounted, and by moving them laterally the cake will be dislodged. (1,158,055, Oct. 26, 1915.)

Zinc-Dust Feeder.—Apparatus for emulsifying and feeding zinc-dust in measured quantities in accordance with the gold and silver content of cyanide solutions, is shown in vertical section of Fig. 4, being patented by HERBERT C. COLBURN of Victor, Colo. It consists of a supply bin 3 for zinc-dust, under which is mounted a screw conveyor 7. The latter is intermittently rotated by a friction ratchet 8 and oscillating member 9 which, by means of an adjustable pitman 10, is connected with gearing driven from a line shaft not shown. The pebble mill 20 is driven from the same line shaft. The dust discharged

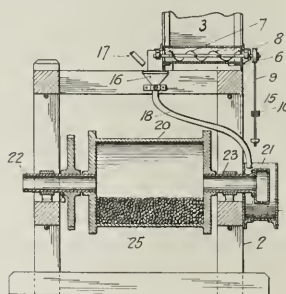


FIG. 4—ZINC-DUST FEEDER

by the action of the screw falls into a bowl 16, from which it is borne to the pebble mill by a stream of barren solution issuing from pipe 17. The quantity of zinc-dust fed to the mill during any fixed period is determined by the capacity of the scoop 21, and the rate of velocity of mill rotation, so that there will be a continuous uniform discharge of emulsion from the hollow trunnion of the mill after the ma-

terial has been subjected to the grinding and emulsifying action of the pebbles, of which the mill is about one-third full. (1,149,426, Aug. 10, 1915.)

Copper

Melting and Refining Copper.—An improvement on the practice of melting and refining copper in a furnace having silicious walls and bottom is contained in the specifications of patent granted to LAWRENCE ADDICKS of Perth Amboy, and CLARENCE L. BROWER of Chrome, N. J. According to the improved practice the copper is treated in a furnace having walls of chrome brick and hearth of magnesite brick. A furnace thus constructed with basic lining is not subject to the erosion and consequent weakening of the structure as with acid lining. Furthermore, the contamination of the molten copper with slag is practically avoided. The practice is of value in the treatment of the three classes of materials ordinarily dealt with in copper refining, viz., foul material, blister copper and cathode copper. The basic furnace permits the treatment of foul material by itself, without the admixture of large quantities of relatively pure material as in acid-furnace treatment. In refining blister copper the basic treatment diminishes the production of slag. In melting pure cathodes, slag is practically suppressed instead of being formed to the extent of about 3 per cent as in acid practice. In any refining of copper the molten charge after skimming should be covered with a layer of carbonaceous material to avoid further oxidation, and precautions should be taken against the introduction of slag from fuel ash. (1,148,814, Aug. 3, 1915.)

Continuous Leaching Apparatus.—The interest being taken in the leaching of copper ore is reflected in apparatus patented by M. C. GODBE of Salt Lake City, Utah, for the continuous treatment of ore by the principle of counter-current flow of solution. The device consists of an annular rotating table, the deck of which is divided by radial partitions into segmental filter units. Beneath the table is a stationary annular launder divided into compartments corresponding in number with those of the deck, and provision is made for the filtrate to flow into this launder. Above the table deck are stationary solution boxes or launders occupying positions above the radial partitions which divide the deck into filter units. Means are provided for feeding the ore onto the table and for removing it after it has been leached. Injectors or air-lifts are also provided for transferring the filtrate from any compartment of the launder beneath the table to the next preceding solution box above the table, in relation to the direction of rotation. In operation the ore is delivered onto the revolving deck in a uniform layer, and as the table revolves it brings the ore on each unit successively under the boxes from which leaching solution is delivered over the charge. As the ore progresses from the point of feed to that of discharge it is acted upon by solutions of gradually increasing strength, and when it reaches the last step in the treatment it receives the strong or barren solution. Water is used for displacing the barren solution just before the ore is discharged from the table. Since the injectors transfer the solution in counter-current to the "flow" of ore, the liquid becomes enriched in metal content as it progresses toward the point of initial treatment, whence it is drawn off for recovery of metallic copper. (1,150,263, Aug. 17, 1915.)

Nitric Acid Treatment of Copper Ores.—In the issue of this journal for November, 1911, page 571, there was a description of the so-called Rankin process of ore treatment. Those who are interested in following the matter still further will find the claims for nitric acid

treatment disclosed in a patent granted to HARRY D. RANKIN of Crafton, Pa. The process is about to be operated by the Nevada-Douglas Consolidated Copper Co., at Ludwig, Nev. (1,150,787, Aug. 17, 1915.)

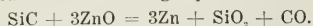
Electrolysis with Revolving Electrodes.—Electrolytic apparatus for the treatment of copper solutions at greater efficiency has been patented by WILLIAM E. GREENAWALT of Denver, Colo. The essential feature of the device lies in means for rotating the anodes in order to bring about a rapid change of solution in contact with the electrodes. A diaphragm separates the cell into anode and cathode compartments. The invention is applicable to the treatment or cyanide solutions of gold and silver as well as to those of copper salts. (1,144,538, June 29, 1915.)

Zinc

Device for Cleaning Retorts.—An invention which may be described as a "vacuum cleaner" for the retorts of a zinc furnace is described in a patent issued to NICHOLAS L. HEINZ of La Salle, Ill. The object of the invention is to reduce dust losses in cleaning retorts and conveying the dust to a place of deposit. A vacuum pipe is extended along the front of a furnace, with a plurality of fittings to which a flexible hose can be connected. The flexible hose terminates in a pipe which is inserted into the retorts, and through which the dust is drawn to a suitable container. (1,160,077, Nov. 9, 1915.)

Roasting Zinc Flotation Concentrates.—The difficulties encountered in roasting the fine concentrates produced in the flotation process have resulted in devising various means of roasting such material without entailing excessive dust losses. One of these is disclosed in a patent granted to LOUIS C. DREFAHL of Cleveland, Ohio, the patent being assigned to the Grasselli Chemical Co. of Cleveland. The essential features of the invention consist in mixing the fine concentrates with moisture to make a plastic mass, and possibly with a binder such as ferrous sulphate. This mixture is then conditioned in a pug-mill and then expressed through a perforated plate, issuing in a number of streams of pulp, each about the diameter of a lead pencil. These fall onto an endless moving belt and break up into short fragments, and are carried by the belt through a furnace chamber where they are dried by hot gases. The material thus treated is said to withstand handling by shoveling or otherwise without much further disintegration, and can be roasted without undue dust loss. (1,153,203, Sept. 14, 1915.)

Smelting Zinc Ores.—With the object of increasing the yield of spelter in the smelting of zinc ores, and simultaneously decreasing the production of blue powder, SAMUEL PEACOCK of Philadelphia, Pa., has patented a process of smelting zinc ores by substituting silicon carbide for carbonaceous fuel in the smelting mixture. The reaction of the mixture would be represented in the following equation:



With three equivalents of zinc being given off, the concentration of zinc vapor in the furnace gas would be three times as great as with the present method of smelting, and therefore a much larger proportion of the zinc in the ore would be recovered as molten metal without reducing the concentration of vapor to the point where blue powder would be produced. (1,154,802, Sept. 28, 1915.)

Recovery of Zinc from Zincky Slags.—Attempts have been made at various times to recover in an economical way the zinc contained in slags produced in Western smelters. One of these is outlined in a patent

granted to SEWALL TRUAX of Canon City, Colo. The process was used for a short time at Canon City on zinky slag from the dump of the United States Smelting Co. The principle of the method is to melt the slag in a reverberatory furnace, the hearth of which is composed of reducing material, such as a mixture of coke dust and clay. The coke reduces the zinc compounds to elemental zinc which is then volatilized. Later the zinc is converted into oxide in the atmosphere of the furnace, and this is collected in a bag house. The consumption of carbon is about 20 per cent of the zinc driven off; or, in the case of a slag containing 10 per cent zinc, the consumption of coke is about 2 per cent of the weight of slag treated. The inventor states that experiments indicate that the zinc above 0.5 per cent to 0.6 per cent of the weight of the slag is readily removed. Of course the hearth of the furnace has to be renewed from time to time. (1,155,628, Oct. 5, 1915.)

Hydrometallurgy of Zinc.—In the accompanying Fig. 5 we illustrate in diagrammatic form the steps in a process for the extraction of zinc from its ores and the electrodeposition of zinc thus extracted. The

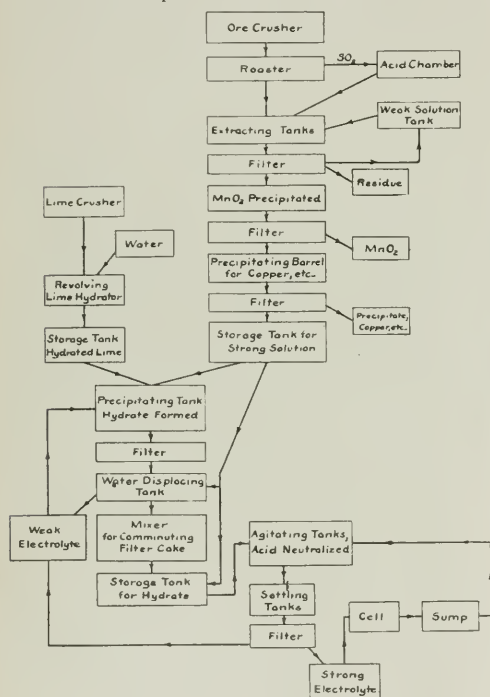


FIG. 5—HYDROMETALLURGY OF ZINC

process is one patented by OTTO BEST of San Francisco, Cal. The features of the process lie in the purification of the zinc sulphate solution before electrolysis. The prepared ore is leached with sulphuric acid. Iron, alumina and silicic acid are removed by treatment with lime, followed by filtration. The next step is the removal of manganese by adding to the zinc sulphate solution an alkaline permanganate, such as calcium permanganate, in the presence of lime or calcium carbonate. This precipitates manganese as the dioxide which is filtered off. Copper is then removed by treatment of the solution with an excess of granulated zinc

and removed by filtration. The filtrate is now practically pure zinc sulphate solution, and as much of it as is needed is used to fill and keep filled the electrolytic vat. Zinc hydrate is now precipitated from solution by means of hydrated lime. The precipitate is filtered and the water therein displaced with strong electrolyte, after which the precipitate is held in suspension and fed to the acid neutralizing tanks as required. From the cell the acid electrolyte passes to a sump where suspended matter is removed, after which the electrolyte passes to the acid neutralizing tanks where the acid is neutralized with the zinc hydroxide precipitate. Neutralization and electrodeposition are effected cyclically by means of the freshly precipitated zinc compound, without, however, diluting the electrolyte, the strength and purity of which are constantly maintained. (1,154,602, Sept. 28, 1915.)

Extraction and Electrolysis of Zinc from Smelter Fume.—In a patent granted to OTTO BEST of San Francisco, Cal., the inventor describes his method of treating smelter fume for the recovery of contained zinc. The experiments were performed on a smelter fume containing from 30 per cent to 35 per cent zinc in the form of oxide and sulphate. The fume is first roasted at a temperature below that of sulphatic roasting. By this treatment the material is rendered filterable; the organic matter is destroyed; the material is freed from arsenic which can be recovered; iron is oxidized and rendered practically insoluble in weak acids, and small amounts of sulphides are oxidized to oxides and sulphates.

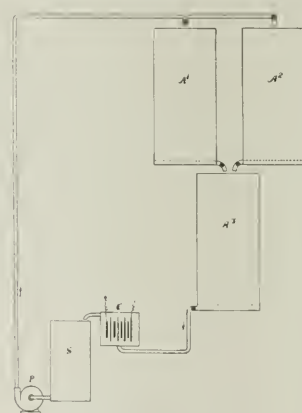


FIG. 6—ELECTROLYSIS OF ZINC SULPHATE

The roasted material is then leached with weak sulphuric acid, whereupon zinc is dissolved and a solution obtained which is much purer than one produced by leaching the unroasted fume. All impurities can be removed by zinc oxide and a little sodium sulphide, used either successively or in one process, according to the impurities present. From the highly purified zinc solution zinc hydroxide is now precipitated by means of a caustic alkali, and soluble impurities removed by washing and filtration. Electrolysis of the zinc compound can then be accomplished by a manner illustrated in Fig. 6 in which *C* represents a cell filled with zinc sulphate. This runs over into a storage tank *S* and contains zinc sulphate and some sulphuric acid. A pump *P* lifts the solution to two filters *A*₁ and *A*₂, having false bottoms and filled with the precipitated zinc hydroxide mixture. The solution is run through these filters at such a rate as to produce the desired acidity in the cell *C*. The practically neutral solution from these filters may pass through another filter *A*₃, which also contains zinc hydroxide precipitate, to get rid of any possible traces of free acid, and then delivered to the cell *C* in a pure neutral state, when a small amount of sulphuric acid, best suited for the electrolysis, is added. (1,154,601, Sept. 28, 1915.)

Synopsis of Recent Chemical and Metallurgical Literature

Zinc

Lungwitz Zinc-Smelting Process.—At a recent meeting of the New York section of the Mining and Metallurgical Society of America, Mr. WOOLSEY MCA. JOHNSON gave his experience with an unsuccessful attempt to operate the Lungwitz process of smelting zinc ores under such pressure that the zinc vapor was kept liquified. This process was patented by Dr. Emil Lungwitz about twenty years ago, and some spelter was produced experimentally by Dr. Lungwitz and Dr. Robert C. Schupphaus in Berlin. On the basis of the experimental work, Mr. John E. Dwight fathered a scheme to try the process on a larger scale for the treatment of a complex zinc ore, obtaining copper matte, lead bullion and spelter. The ore tested was from New Hampshire and contained 20 per cent zinc, 7 per cent lead and 1 per cent copper in a mica gangue. The pressure blast furnace was erected at Warren, N. H. The talent engaged comprised Fred C. Gordon, E. A. Uehling, D. V. Keedy, Carl F. Dietz and Mr. Johnson.

"The apparatus used was a round, pressure blast furnace, 3 ft. inside at the tuyeres, 5 ft. 6 $\frac{3}{4}$ in. at the bosh, with a height from tuyere line to charging floor of 25 ft. 3 in. The furnace was supported by four steel battered columns of latticed channel bars. The crucible was thus exposed to view. Five 3-in. water-cooled tuyeres were used, in each of which a bronze plug with three $\frac{7}{8}$ -in. holes diffused the blast into the smelting zone. The shaft was made of $\frac{7}{8}$ -in. plate, triple riveted. The charging was done by a massive double bell and hopper of cast steel. The pressure in the furnace was regulated by two "bleeders" on top, like safety valves. The crucible and bosh were lined with chrome brick, and the shaft with good fire brick. It was possible to spray with cooling water any section of the furnace, which was blown by a two-stage Ingersoll-Sargeant 7-drill compressor giving 1000 ft. of free air per minute. In general, it resembled a conventional iron blast furnace, modified to meet the imposed conditions of operating at 60 lb. pressure. The engineering effect was as good as could be desired, when the unusual and difficult nature of the feat was considered.

"As a result of discussion it was seen that the pressure and temperature limits of the smelting zone would be at least narrow. It was accordingly determined to make a pressure-temperature curve of the system "liquid-vapor zinc" and fluidity tests on the running points of various slags.

"For the first-named purpose, after several trials a 'bomb' was made of a piece of 5-in. shafting 30 in. long, drilled with a 3.5-in. hole. In one end, the lower, an outside hole was drilled to receive a pyrometer couple in close proximity to 500 grams of spelter. The bomb was placed inclined in a small kerosene-fired reverberatory so that the upper end projected through a luted hole in the furnace. There was a pipe connection from this to a small receiver, which had a pressure gauge and a relief-valve operated by hand. In this way the line pressure of 120 lb. could be controlled to any desired pressure from zero to 120 lb. In the bomb, 3 in. from the molten zinc was a 0.01-in. hole and 3 in. from this a second 0.01-in. hole. The bomb was filled with coke (88 per cent fixed carbon) sized between 4-mesh and 10-mesh. Thus, when the bomb was under heat and pressure two small flames of carbon monoxide burned from these two tiny apertures. When the pressure was slowly reduced, the carbon monoxide flames suddenly changed to brilliant zinc flames when the boiling pressure of zinc at that temperature was reached.

"After some failures, we found it necessary, after each determination of the boiling point of the zinc, to increase the pressure so as to clean the coke from all zinc either as liquid or vapor. In this manner all false flames caused by "fuming" were eliminated. It was also found necessary to shut off the oil flame while taking the readings, as the indicating flames were otherwise not easily visible. When the details of operation were understood, accurate and comfortable results were attained. The curve above the boiling point of zinc at atmospheric pressure, i.e. 920 deg. C., is nearly a straight line, and for each pound increase in pressure the boiling point is raised 6.1 deg. C.; at 25 lb. it is 1080 deg. C.; at 75 lb., 1350 deg. C.

"For determining the fluidity of slags we used the Johnson slag-tester, described in *Trans. A. I. M. E.*, Vol. XLIV, page 139. This gives accurately the temperature at which the slag in question drips through a small hole, a point analogous to that at which the slag in the smelting zone drips over the coke. We made and tested about 70 slags, and finally determined on a sesquisilicate containing 8 per cent CaF_2 , 15 per cent FeO , 5 per cent Na_2O , remainder lime and silica. This slag is fluid at a few degrees above 1000 deg. C., whereas lead blast furnace slag is fluid at about 1100 deg. C. It was impossible for use to use a high percentage of ferrous oxide, for fear of formation of "iron sows," under the more intense reduction needed in the Lungwitz process.

"With knowledge of these factors, we could operate the furnace with some degree of certainty. There was raised, however, the question of "the law of partial pressures." For liquifying any vapor, the full pressure of the vapor must exist next to the surface of the liquid. Now, in the furnace operations at Warren, for each cubic foot of zinc vapor there were some 9 cu. ft. of indifferent gases, carbon monoxide and nitrogen, sweeping through the smelting zone. Accordingly, should any zinc be liquified it would be evaporated by this sweep unless the pressure were ten ($9 + 1$) times as large as had been considered and calculated. The condition was analogous to a steam condenser with too much air in the system. This point was brought out in discussion, but it was decided to start at any rate. It was found later that it militated strongly against the success of the Lungwitz process.

"The furnace was started, after three weeks' overhauling had made it tight to 80 lb. air pressure, by inserting a torch through the tuyeres and lighting cord wood on which was a charge of coke. Above that was a burden of coke and slag-making materials. Tests of the charging, pricking the tuyeres, and tapping slag were made. The pricking of the tuyeres made an infernal racket, but could be done successfully. Finally the slag level came up to the height of the tuyeres and a test of the slag-tapping arrangement was made. This was designed with a cast-steel hood in the form of a large ell over the slag notch, to which was bolted a cast-iron cylinder leading to a brick run-way for the slag. In the cast-steel were two holes, through the lower one of which a modified Scott "mud botting-gun" could be inserted. Through the upper hole, the tapping bar could be inserted. While the entire force retired to a considerable distance on the side hill, the writer and Mr. Allen, now superintendent of the Columbia works of the National Carbon Company, with internally repressed trepidation but with all possible show of sangfroid, attacked the position of the enemy. The bar was driven in with ease. On pulling it out, the slag was voided instantaneously in a large aerated mass, and ran down the run-way like a thing possessed; the mud-gun was next pushed by the pneumatic cylinder

against the slag-hole and the bott sent home. Contrary to my expectation, the tapping of slag and botting the furnace under 60 lb. pressure was successful in its first trial. Later, we repeated it at the working pressure of the furnace, and so long as the crucible of the furnace was hot and its contents liquid there was little trouble. The charging of the furnace gave but little trouble as the heavy bell and hopper were actuated by powerful air cylinders, and pieces of charge on the bearing surfaces could be shattered.

"The furnace ran along for three weeks but finally froze. I think that steam from the wet charge condensed in the ganister filling between the shell and the lining and finally made its way to the crucible. At all events, a lot of water got into the crucible, while there was no leak from the cooling systems. The furnace made no spelter at all, but the lead produced carried a few tenths of zinc. As the reduction was intense, the slag analyzed only a trace of lead. Some zinc, as was natural, was carried up the shaft and condensed. In a longer campaign, I believe that bad scaffolding would have occurred at intervals. The work at Warren was abandoned after this test. Mr. Gordon later built a furnace near Philadelphia having a shaft 60 ft. high and 4 ft. in diameter, with a condenser near the bosh. He finally made a few thousand pounds of spelter. With his death, the work was given up.

"We can thus chronicle the last and most serious attempt to make spelter in the blast furnace. The work was done with elaborateness, without regard to expense, and with all possible engineering care. It can be concluded that inherent metallurgical difficulties prevented the success of this scheme and will prevent that of any other similar scheme. In short, while a brilliant attempt had attained some success in working out apparently insuperable practical details to a certain degree, the law of partial pressures attacked the very heart of the process and made it faulty in theory."

Gold and Silver

Metallurgy of the Sons of Gwalia Ore.—In our issue for Dec. 1, 1915, we gave a synopsis of certain features of the plant of the Sons of Gwalia, Australia. This is now supplemented by some metallurgical details from an article by THOMAS B. STEVENS in the September *Journal* of the Chamber of Mines of Western Australia.

The ore is a sulphide of iron in a gangue of highly sheared greenstone schist containing quartz and calcite. Following is a typical analysis:

	Per Cent
Silica	68.40
Alumina	9.71
Ferric oxide	1.85
Calcium oxide	3.61
Calcium carbonate	11.94
Magnesium oxide	2.15
Pyrite	3.15
	99.91

The value of the gold content is slightly over 30s. (\$7.50) per ton; the gold is alloyed with one-twelfth its weight of silver. Free gold occurs in the quartz, but the pyrite is the richest part of the ore. The following grading analyses on a sample crushed to pass 30-mesh show the distribution of the value in the original ore and after it has been amalgamated.

Grade	Per Cent	Assay Value in Shillings Before Amalgamation	Assay Value in Shillings After Amalgamation	Extraction on Grade, Per Cent
+ 60	17.9	39.8	38.9	2.3
+ 150	20.2	46.0	30.9	30.5
- 150	14.4	112.0	26.0	76.8
Colloidal slime	47.5	12.0	8.0	33.3
Bulk (calculated)	100.0	38.2	29.3	46.8

Extraction by amalgamation is seen to be highest on the minus 150-mesh grade, even though this contains the greatest percentage of mineral; but equally

good extraction can be had on the plus 150-mesh grade if it is ground fine enough. For successful cyanide treatment, the economical limit of grinding is minus 150-mesh.

A feature of the rock-breaking plant is the use of a gyratory to crush in one operation a large tonnage suitable for stamp feed. The gyratory is well suited to the crushing of this ore, the greater part of which comes in flat slabs which would pass a jaw breaker without being crushed.

Stamps weigh 1225 lb. when new, having been increased in weight from 1000 lb. The old camshafts, 5½ in. in diameter, are found too light for the additional weight and show a short life. Cast-iron dies are used, as it has been found that a more constant tonnage can be crushed than with steel dies, on account of a more even wearing surface being maintained under the shoes. When crushing through screen of 0.097 sq. in. aperture, with a 4.75:1 ratio of water to ore, a duty of 10 tons per stamp per day can be maintained.

Grinding pans and tube mills are used for fine grinding. The former were part of the original equipment and are still used for amalgamating a part of the gold. Recovery by this method amounts to 20 per cent of the total, and the removal of so much gold at this point relieves the cyanide department of possible losses from high-grade solutions and soluble gold loss at the filters.

The following table compares the work of the different grinding machines:

	Total Cost Running One Unit One Day	Tons —150 Grade Produced Each Day per Machine	Percentage of Total Tonnage of —150 Grade Produced	Cost of Producing One Ton of —150 Grade, in Pence	Tons —150 Grade Produced per Hip. Day
Five stamps	2.65	18.0	38.0	35.4	1.20
Pan	1.36	7.4	15.0	44.0	0.59
Tube-mill	5.17	54.0	33.0	23.0	1.20

Some interesting figures have been compiled to show what proportion of the gold is dissolved at various points in the process. In each case estimates were made by determining the difference between the assay value of solutions entering and leaving the machines and then calculating to tons of dry slime.

	Shillings per Ton	Per Cent of Total Gold Dissolved
In battery boxes, less than	0.5	1.5
In pans	6.5	19.4
In tube-mills	2.7	8.0
In launders, classifiers and thickeners (estimated by difference)	5.0	14.9
In agitators	9.6	28.7
Total dissolved	24.3	72.5
Amalgamated in pans	6.7	20.0
Left in residue	2.5	7.5
Value of original	33.5	100.0

A high filter duty is obtained due to the porous nature of the slime. Using a vacuum of 27 in. and a pulp of 40 per cent solids, a cake 3 in. thick and containing 28 per cent moisture and 20.5 lb. dry slime per square foot can be obtained in 20 min. Each square foot of filter cloth filters nearly 20 tons of slime before it is discarded.

Loss of soluble gold in discarded slime is 3d. (\$0.06) per ton, and cyanide loss is under 0.1 lb. KCN.

In order to get good precipitation it is necessary to maintain the zinc-lead couple in the boxes. This is done by allowing a drip of lead acetate to run continuously, delivering about 0.3 oz. per ton of solution. This has been more efficient than coating the zinc with lead or introducing lead salts at the tube-mill or agitator.

The cost of treatment for the past six months, on an average tonnage of 13,534 tons has been:

Rock breaking and transport.....	\$0.0888
Stamp milling.....	.2678
Pan-grinding and amalgamation.....	.1456
Tube-milling.....	.1902
Agitation and filtration (including all water used for treatment purposes).....	.5490
Precipitation and smelting.....	.1504
Cost per ton.....	\$1.3918

Cyanide Consumption on the Rand.—In an extensive article by H. A. WHITE in the September, 1915, issue of the *Journal of the Chem. Met. & Min. Soc. of South Africa*, the author gives the results of his investigation into the causes of cyanide loss in Rand mills. The average consumption of cyanide on the Rand for 1914 was 0.4 lb. per ton of ore treated, and the annual requirement was about 5000 tons.

An estimation, as NaCN, of the amount of total cyanide, ferrocyanide and sulphocyanide in sand residue as discharged at the Simmer Deep showed a loss of 0.0344 lb. NaCN per ton of pulp in sand treated. A similar estimation on settled slime after treatment and before discharging showed a loss of 0.1219 lb. NaCN per ton of pulp in slime treated. Similar experiments with sand and slime at the Rose Deep showed NaCN losses per ton amounting to 0.0583 lb. and 0.0653 lb. respectively.

To determine the loss due to the escape of HCN from exposed solutions, experiments were conducted with sump solutions in glass jars of 300 c.c. capacity and a surface exposure of 84 sq. ft. per ton of solution, compared with 5 sq. ft. in a sump 6 ft. deep. The results showed that loose or incomplete covering is useless in preventing loss of cyanide; that with weak solutions little loss as free cyanide occurred while protective alkali was present; that with strongest solutions the loss, both as free and total cyanide, became serious when protective alkali fell below 0.01 per cent NaOH, and, finally, that zinc in solution greatly decreased the loss of HCN due to hydrolysis.

A further experiment was made with strong and weak stock solutions and new solutions without protective alkali, by placing duplicate quantities of each in open vessels and stoppered bottles, and titrating the free cyanide in each sample at intervals from six to ninety-five hours. The exposed solutions suffered notable losses of cyanide while the stoppered solutions remained at almost original strength.

Exposure tests with working solutions under varying conditions of temperature, time, alkalinity and cyanide strength, showed that the loss is much greater in pure synthetic solutions, even with added alkali, than with ordinary stock solutions; that higher temperature increased the loss; that high protective alkalinity reduced the loss by preventing hydrolysis.

Prevention of Hydrolysis in Cyanide Solutions.—This subject is exhaustively treated by HUGH M. LESLIE in the *Journal of the Chem. Met. & Min. Soc. of South Africa* for September, 1915. The author regards hydrolysis as responsible for great losses of cyanide in the treatment of gold ores, and gives the results of his investigations on the subject. He contends that the evolution of hydrocyanic acid due to hydrolysis is accountable for the large excess of cyanide which has to be used over and above that required for efficient extraction. As a remedy he proposes a "closed" system of cyanidation, in which the vats and tanks are covered. His ideas on this subject have been patented, the United States patent being reviewed in our issue for Dec. 15, 1915, page 972.

In a simple cyanide solution kept at temperatures

varying between 42 deg. and 49 deg. Fahr., the following losses were noted due to hydrolysis:

Interval, Hours	KCN Test, Per Cent	KCN Loss, Per Cent
4	0.368	7.56
24	0.232	37.00
22½	0.116	50.00
23½	0.028	75.80

With higher temperatures the loss is markedly increased, and in agitation with model Brown agitators there is a steady loss as agitation proceeds.

Exposure tests with simple cyanide solutions of different strengths show that the weaker the solution the greater the percentage decomposition. They also show that the alkali formed as a product of hydrolysis has little or no protective action on the remaining cyanide, and that hydrolysis proceeds until all the cyanide is consumed.

In contrast to these experiments, the author conducted tests in closed vessels, showing that the loss of cyanide is very small as compared with that in open vessels. He concludes that a very great loss must occur from hydrolysis in actual practice where the vessels are open, and that great protection can be afforded by a "closed" system.

In order to confirm his theories in actual practice he conducted tests at operating plants. At one mill he made tests on the slime department only, showing that there was a loss of cyanide due to evaporation amounting to 0.0013 per cent KCN per twenty-four hours, aggregating 32,572 lb. of cyanide (100 per cent strength) per annum. This figure did not include the losses in other departments, but serves to show the enormous loss which may be attributed to hydrolysis.

Parallel leaching tests were then made on a small scale with open and closed systems, in order to get comparative data on cyanide losses. The following average figures for cyanide consumption were obtained:

	KCN, Per Cent	Per Ton, Lb.
Open system.....	100	0.9375
Closed system.....	100	0.6283
Open system.....	130	0.4900
Closed system.....	130	0.3290

This shows a difference per ton of 0.2092 lb. 100 per cent KCN, or 0.1610 lb. 130 per cent KCN, or 33 per cent in each case.

The actual consumption in the tests was greater than is obtained in practice at the mill where the tests were made, figures for the latter being about 0.390 lb. 100 per cent KCN, or 0.300 lb. 130 per cent KCN. If these figures are used as representing the actual conditions, and the "closed" system consumption reduced by the difference between these actual figures and the test figures for open system, the comparative figures will be:

	KCN, Per Cent	Per Ton, Lb.
Open system.....	100	0.3900
Closed system.....	100	0.1806
Open system.....	130	0.3000
Closed system.....	130	0.1390

These figures show a saving due to protection afforded by a closed system amounting to 54 per cent in each case, or, based on a consumption of 0.3 lb. per ton with cyanide at 32 cents per pound, it would amount to a saving of about 5.2 cents per pound.

Similar tests on slime in agitators by the closed and open systems showed a saving of cyanide by the closed system. Other tests are given, all of which lead the author to conclude that there is possibility of making a marked saving of cyanide by using a closed system of treatment.

Bromine.—It is announced that the bromine wells near Pomeroy, Ohio, and Mason City, W. Va., have again been put in operation after an idle period of a number of years. The present production is expected to be 5 tons to 6 tons monthly.

A New Electrolytic Cell for Making Pure Oxygen and Hydrogen

The demand for oxygen and hydrogen for various industrial uses has grown very rapidly in the last five years. Certain lines of manufacture have been built up based on the oxygen process of welding, such as welded tanks, steel barrels, automobile parts, tubes, etc., while for repairing broken machinery, for reclaiming castings, for metal cutting of every nature, oxygen and hydrogen or oxygen and acetylene are used in steel mills, railroad shops, foundries and down to the smallest machine shop. Hydrogen likewise is in active demand; it is used more and more for cutting purposes and for light welding; it is also used for lead burning, platinum smelting, in the manufacture of filaments for electric lamps; and to a very great extent in the new industry of hardening oils by the hydrogenation process. This rapid development in the uses of two gases was facilitated by the introduction into this country of oxygen and hydrogen-generating apparatus several years ago. Large users of one or both of these gases were thus enabled to obtain their supply direct from their own generating plant at low cost, in a manner suitable to their individual requirements.

The International Oxygen Company of New York City, makers of the I. O. C. unit type generator, is bringing out a new style of oxygen and hydrogen generator under the name of the I. O. C. bipolar generator.

This type of generator resembles outwardly a filter press such as used in many chemical industries. Rene Moritz, of Wasquehal, France, patented this type of apparatus in the U. S. and elsewhere in 1913, and I. H. Levin, of the International Oxygen Company, who studied under Moritz and Flamand, perfected this machine greatly, and incorporated in it many novel and ingenious features.

Briefly described, the I. O. C. bipolar generator consists of a series of metallic plates (bipolar electrodes) clamped up together in a heavy frame, electrically insulated from one another, and separated by diaphragms of porous fabric. Each pair of these electrodes forms a closed cell divided by the diaphragm. These cells are filled with the electrolyte (caustic potash or soda solution).

An electric current admitted at one end plate passes on through the plates and the solution to the other end plate. In its passage it decomposes the water in the solution into the two gases—oxygen and hydrogen—which are released on opposite sides of each plate and emerge upward into the gas off-takes. The mingling of the oxygen and hydrogen in each cell or compartment is prevented by the diaphragm which, while permitting the passage of the fluid resists the passage of the gases.

As the gases are released and withdrawn water is automatically added from a supply tank. The operation is continuous so long as current and electrolyte are supplied.

In the smaller machines, the electrodes are carried on two steel rods supported on two heavy end pieces or pedestals of cast iron. In the larger generator the side rods are replaced by steel bars. The construction is one of extreme rigidity, absolutely proof against any distortion and consequent disarrangement of electrodes, with resultant leakage. It will be noted that there are only the two end supports—no middle support as in some types—simplifying the problem of erection and alignment.

The electrodes are clamped together by a heavy screw working in the rear support. A feature of special

note in the I. O. C. generator is that a ball thrust bearing is interposed between the end of the clamping screw and the rear end plate—a refinement which contributes to the non-leaking qualities of the machine by doing away with the tendency of the electrodes to "ride up" from the side bars under screw pressure.

The electrodes are of a special patented design, the anode side being heavily nickeled, while the cathode side is of commercially pure iron. This use of two metals has an important bearing upon the efficiency of the generator, referred to more fully later. The surfaces of the electrodes carry vertical corrugations which are interrupted by a large number of recessions to facilitate the flow of electrolyte into the cell and the release of the gases from it.

At top and bottom of each electrode are two openings communicating by a cored channel with opposite sides of the plate. Those at the bottom are for the water intake and those at the top are for the gas off-take. It will be seen that each half of each cell (separated by the diaphragm) has its own independent water intake and gas outlet, so that there can be no possibility of the two gases mingling through these channels. Any gas leakage which may occur between the electrodes escapes to the open air and not into the adjacent cell or into the gas off-takes.

The diaphragms are of especially prepared asbestos fabric, of a thickness and texture carefully worked out by long experiment to give the best results. All around the edge of this fabric is molded a packing rim of pure rubber which rests in a recessed groove on the face of the electrode.

Obviously, in a generator of this kind, an essential of power economy is that all the current supplied the machine shall pass through the electrolyte and none



PLATE WITH DIAPHRAGM

of it be by-passed through the metal of the machine or through the water inlets and gas outlets.

In the I. O. C. bipolar generator the electrodes are insulated from the side bars of the frames by porcelain insulators resting on a wooden bar in the large machine and on fibre in the small machine. They are insulated from one another:—first, by the pure rubber packing rim surrounding the diaphragm; second, by nipples of pure rubber inserted in the water intake and gas off-take shoulders of the electrodes. These nipples, with everything clamped hoe, meeting one another and not only insulating the electrode shoulders but also providing an insulating tube in the interior of the water intakes and gas off-takes.

The gases rising from the electrodes and entering the gas off-takes, carry with them a small percentage of the electrolyte which, if allowed to enter the external piping system, would "ground" the apparatus and permit the escape of current.

To guard against this contingency, there is provided in the gas off-take system insulating pipe sections—each consisting of two sections of heavy glass tube clamped between iron flanges and so devised as to intercept and drain off through an insulating connection the moisture entrained in the gases. The gases go through these insulators substantially dry and free from electrolyte.

The voltage supplied to any electrolytic gas generator is utilized in two ways:—partly in decomposing the electrolyte; and partly in overcoming the internal resistance of the generator.

A number of features of the I. O. C. generator contribute toward high electrical efficiency. First of these is the use of the nickel anode and iron cathode (a patented combination) which has been found to materially facilitate the electrolysis or decomposition, by lowering the "over-voltage." Incidentally, these bi-metallic electrodes prevent the formation of rust and oxides which would materially shorten the life of the apparatus.

A second feature in efficiency is the fact that the design of this generator is such as to retain within the apparatus most of the heat produced as a result of the ohmic resistance. This keeps the electrolyte and the

electrodes at a comparatively high temperature which adds to the efficiency of the electrolytic process. Furthermore, the electrolyte used—a solution of caustic potash—has been found by experiment to utilize the current to best advantage.

The generator is filled, on starting the apparatus, with the solution constituting the electrolyte. Obviously, as decomposition proceeds and gases are withdrawn, water must be supplied to the solution to maintain the right level and right density. On the front of the generator are two tanks or domes with glass water level indicators, which carry the solution. Pipes descend from these tanks to a water-feed manifold which branches into two pipes connecting independently to the two water intakes to the cells and also into two risers leading to the two independent gas domes above. Into these domes the oxygen and hydrogen are separately discharged as generated, the gas off-takes opening through an inverted U below the fluid level.

Next to these domes is a feed-water tank discharging distilled water through a float-controlled valve, as needed, to the solution tank on the front of the generator.

Arrangements are such that the proper fluid level is automatically maintained throughout the system. The two independent water intakes to either side of each electrode absolutely prevent any mingling of oxygen and hydrogen through the water supply.

This water-feed device creates an absolute balance of pressures throughout the generator, the vital importance of which will now be noted. Furthermore, it makes the water feed absolutely proportioned to, and under the control of, the rate of gas generation.

A primary essential in a generator of this type is to minimize circulation through the diaphragms—the function of these diaphragms being only to segregate the two gases as released at the same time permitting the passage of the electrolyte through their pores.

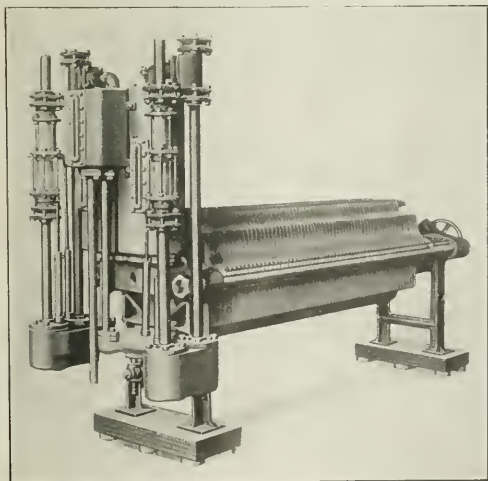
The two independent water supplies—one to either side of each diaphragm, but both under exactly the same pressure due to the hydrostatic head in the solution tank—obviously put the diaphragms under balanced fluid pressure, and eliminate circulation through them due to unequal pressures on their two sides.

This has two vital results. First, it removes any tendency to cause a mingling of gases through the diaphragm. Second, it relieves the diaphragm material from all mechanical stress and obviates any destructive erosive action which might be caused by solid particles in the electrolyte being forced through the fabric. This absolute balance and control of water pressure, then affects both the purity of the gases and the life of the apparatus.

The two gas off-takes discharge into the two independent gas domes already referred to, the gas emerging below the fluid surface through an inverted "U." It is apparent, then, that the pressure on both gases, clear back to the individual cells, is the same—being that determined by the hydrostatic head in the domes through the two independent risers from the water-feed manifold.

This balanced pressure in both gas off-takes prevents any mixture of the gases and contributes to the balancing of pressures on the diaphragms. It will be noted that gas and water pressures are predetermined and constant.

The gases, escaping from the gas off-takes rise through the fluid in the gas domes and pass out through discharge pipes at the top of the domes—thence downward to purgers in either side. These purgers are closed boxes of cast iron filled with water to a certain level. The gases except below the surface of this water, pass



I. O. C. BIPOLAR OXYGEN AND HYDROGEN GENERATOR.
TYPE G

upward through it, and emerge thence through the supply lines to the gas holders.

The function of these purgers is three-fold:—first, to catch any entrained fluid in the gas; second, to cool the gas; third, to act as a water-check-valve protecting the pressure system of the generator from any undue pressure of the gasholders.

A signal whistle is provided which gives notice when the level of the solution in the generator falls below the described limit. Glass sight-feed indicators on the solution tank and gas domes show the fluid levels and reveal the generation of the gases. Gauge glasses connecting with the electrodes at intervals along the generator show the fluid levels in the body of the apparatus.

To permit the emptying of solution from the generator when required, drain valves are provided. These are of the lever-operated gate type, designed to obviate any leakage or wear due to the presence of solid matter in the fluid.

To summarize, the notable features of the machine are:

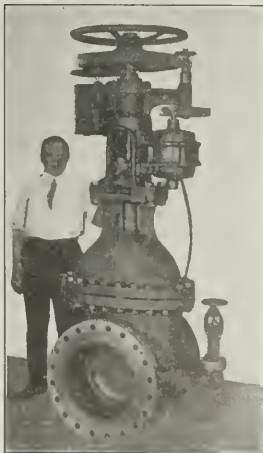
First, the water feed to the generator is automatic and controlled entirely by the quantity of gas that the generator makes.

Second, the water feeds to the oxygen and hydrogen compartments are entirely independent, preventing mechanical transportation of the gases.

It is not to be inferred from this that the company recommends that these machines be started and then left absolutely to themselves. No mechanism is perfect—and the best apparatus made deserves a fair measure of consideration and attention. But it is claimed that the I. O. C. bipolar generator certainly calls for the minimum of attendance—at the most, only a small part of one man's time. And this feature contributes largely to the low cost of gas production to be realized by this apparatus.

New Uses of Monel Metal

Monel metal, the well-known alloy of approximately 68 per cent nickel, $1\frac{1}{2}$ per cent iron and $30\frac{1}{2}$ per cent copper, is finding its greatest uses and possibilities as an engineering alloy owing to its great strength and non-corrosive properties. The metal is commercially available in ingots, sheets, rods, castings, wire and a variety of other forms. The U. S. Government, through the Navy Department, has made tests which led them to specify it for outboard connections of battleships which would be rapidly corroded by sea water. Valves, valve seats and liners of cast Monel metal for pumps have been found very useful. Liners show no scoring, and after a short period of use assume a glass-like finish which reduces the packing to a minimum. The U. S. Navy requires all pumping equipment of ships be furnished with Monel metal.



IMMENSE VALVE FOR SUPER-HEATED STEAM

In connection with very high steam pressures, where superheated steam is used, the alternate heating and cooling of bronze and steel valve seats cause them to become granular and crumble away. Monel metal has been given a severe test and found entirely satisfactory. A large valve of Monel metal weighing 3500 lb. is shown in the accompanying illustration. This valve was made by the Nelson Valve Company of Philadelphia for the Philadelphia Electric Company's new station, where the largest steam turbines in the world (30,000 and 35,000 kw.) are installed. This valve is made to withstand 250 lb. pressure and 800 deg. Fahr.

Monel metal castings have found a varied use where chemicals or other corroding agents must be handled, such as in washing apparatus; acid conductors, in refrigerating plants where the ammonia causes rapid corrosion; for pickling apparatus in connection with the rolling of steel sheets and tin plate. Several of the largest mills for rolling steel sheets have recently changed their entire equipment from iron to Monel metal. Among such plants may be mentioned the Illinois Steel Company, the West Penn Steel Company, and, most notably, the Vandergrift Plant of the American Sheet & Tin Plate Company, which is the largest rolling mill in the world.

Electric Power Development in the Pittsburgh-Wheeling District

The American Gas & Electric Company, 30 Church Street, New York City, owner of several operating plants throughout the Eastern and Central States, has purchased about 600 acres of land at Beech Bottom, or Windsor, W. Va., on the Ohio River, between Wellsburg and Wheeling, and is proceeding with the erection of a large electric power plant on a portion of this land.

This will be a wholesale plant; that is, it will supply power to the company's present plants at Wheeling, Canton, Newark, etc., and will also be in position to furnish power to other electric companies, street railways, manufacturers, etc.

The original installation will consist of two 30,000-kw. turbines, or a total of 60,000 kw. The plans, however, contemplate an ultimate capacity of 200,000 kw.

The plant is designed by Sargent & Lundy, Chicago. Contracts have been let to the Foundation Company, New York, for the installation of intake tunnels, building foundations and turbine foundations. The General Electric Company will furnish the turbines and Babcock & Wilcox Company the boilers. It is expected the plant will be ready for operation some time in 1916.

Contract has been made with a neighboring mine to supply the fuel requirements of the entire plant for the next forty-five years.

A double-circuit heavy steel line will be at once constructed to Canton and operated at 140,000 volts. Connection will also be made with the company's present system at Wheeling and Newark.

This new installation is expected to attract to the Pittsburgh district a number of industries to whom cheap electric power is an essential. It is planned to supply local business adjacent to the plant at 11,000 volts directly from their busbars, and it is the intention to invite consumers with high-load factors, such as chemical and steel furnaces, to locate near the power plant. With this in mind, the American Gas & Electric Company, in making their purchases of land, secured sufficient acreage to accommodate a number of such industries adjacent to the generators.

The statement is made by the company that the low price of coal in this district, the abundance of condensing water, low cost of disposal of ash, which will be

used to fill up lowlands, and the absence of high tax rates will make it possible to produce power at a cost which will enable them to sell it to consumers cheaper than it would be possible for the latter to manufacture it themselves.

Device for Reversing Open-Hearth Steel Furnaces

The Schumann device for reversing open-hearth steel furnaces, which is described in the following note, has been in continuous operation for the past seven months in a large steel plant in Maryland and has given full satisfaction. Its operation is shown in Fig. 1.

1 is the open-hearth furnace which is to be reversed every twenty minutes, 2 is a clock with hour hand forming a contact which operates the solenoid 3. The plunger 4 is thereby raised, opens the four-way valve 5, which controls the passage of air, water, etc., through the pipe 6. The air or water enters the cylinder 7 and pushes the piston 8, which slacks the cable 9, dropping the water-cooled damper 10 and shutting off the stack draft. When the water-cooled damper drops, the clamp 11 hits the nut 12, which raises the damper 14 by the pulling cable 13. This lets in the air, which goes to the checkers and then to the furnace. The damper lid can be adjusted, letting more or less air come in by the screw device 15.

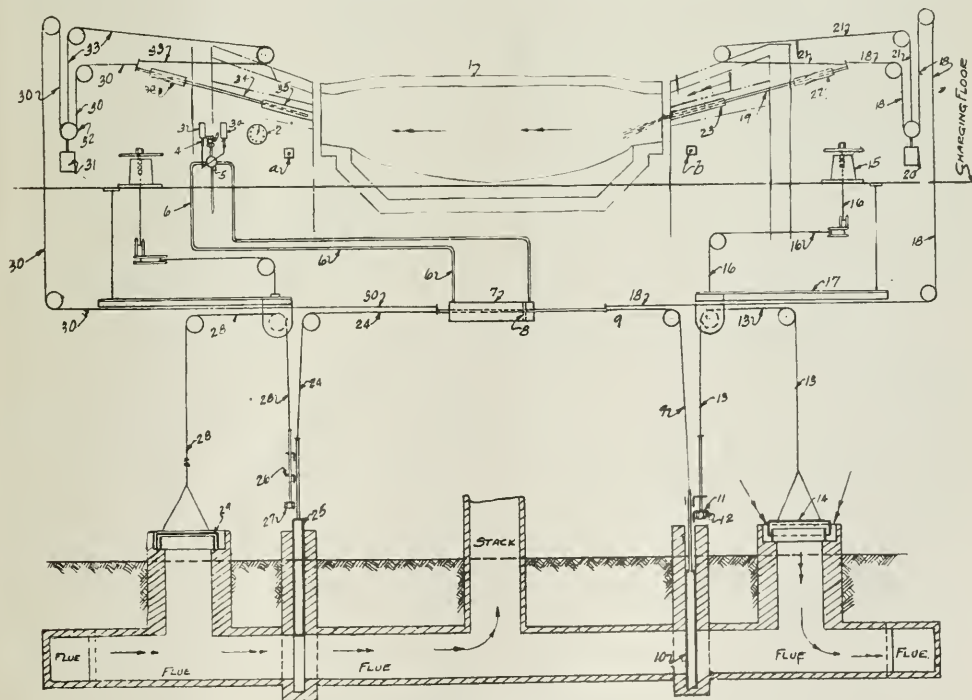
When the piston 8 is over it will permit slack on the cable 17. When the cable 18 is slack the burner 19 will slide into the furnace and automatically starts operating. There is sufficient slack in the cable 18 so that the counterweight 20 will drop, pulling the cable 21, which pulls the burner 19 into the furnace. Cylinders 22 will open, letting on the steam and oil the moment the burner starts sliding into the furnace. Cooler 23 will

protect the burner 19 when in and out of operation.

In case it is desired to reverse the furnace in less than twenty minutes, the button *a*, operating solenoid 3, is pressed. When the piston 8 is pulled over it has also pulled on the cable 24, which raises the water-cooled damper door 25, letting the stack draft pull on this end of the furnace. When the door 25 is raised up, the clamp 26 attached to it raises the nut 27, slackening the cable 28, which lets the damper lid 29 close, shutting off the air from the checkers. Piston 8, when pushed over, pulls on cable 30, which pulls the burner out of the furnace. Cable 30 raises the counterweight 31 and the sheave 32, which in turn slacks the cable 33 so that the burner 34 will come out of the furnace. The counterweight will then take up slack in cable 30, which is left over, so the burner 34 will remain out. When the burner 34 slides out it lays in cooler 35, which prevents it from being burnt up by flame from the opposite burner. When the burner starts sliding out of the furnace it ceases operating instantly, cylinder 36 shutting off the oil, steam or air.

When the furnace is ready to reverse twenty minutes later, the clock hand will touch the next contact point operating solenoid 3*a*, which opens the four-way valve and then operates everything in the opposite manner. If it is desired to reverse in less than twenty minutes, the button *b* is pressed. In case it is not desired to use the cable device to pull burners in and out of operation, a small slide valve can be used which lets the air, steam, water, etc., go to the small cylinders operating the burners in and out. When wanting to cool the furnace quickly for any particular reason, water-cooled dampers 10 and 25 are hung up, which will let the stack pull on the furnace from both ends.

This device is made by the Codd Tank & Specialty Company, Baltimore, Md.



SCHUMANN REVERSING DEVICE

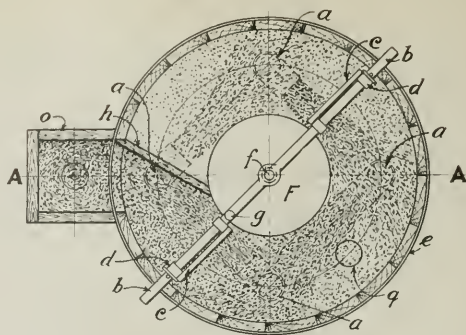
Flotation Test Tank for Mill or Laboratory

In cyanidation it is considered safe and good practice to run pilot tests on the pulp parallel with the commercial treatment. In oil-flotation treatment the same rule should hold good. For this reason a small tank suitable for pilot-testing at operating commercial plants or in the laboratory has been designed by the Parral Tank System of Agitation, I. W. Hellman Building, Los Angeles, Cal. Although the apparatus and the principles of operation are patented, the free use of this tank is offered to any one for testing purposes.

Fig. 1 shows the dimensions of this tank and the operating apparatus embodied in its construction from which the tank may be made at any works. If the air pressure available for use is found too high, a short rubber or canvas sleeve may be slipped over the discharge orifice of the transfer pipes and directed downward in the tank charge.

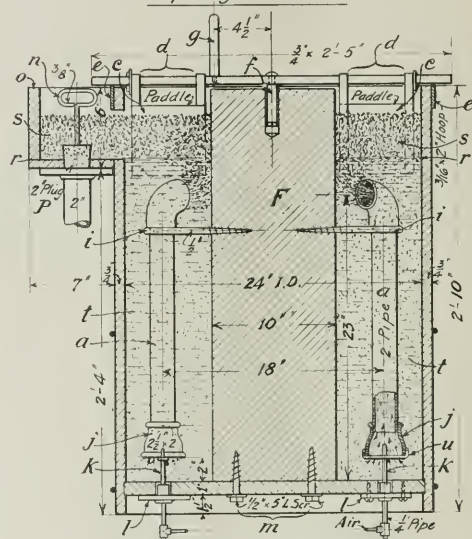
The various parts of the tank and apparatus are lettered in the drawing as follows:

- AA is the line through plan view of top of tank on which the vertical elevation is drawn.
- a are transfer pipes through which the pulp is continuously drawn from the bottom and spouted 2 in. underneath top of tank charge.
- b is the arm from which the skimming paddles *c* are suspended.
- c are skimming paddles (pieces of rubber belt), 8 in. x 8 in., attached to, but swinging loosely on, the arm *b* by strap hinges *d*.
- d are the strap hinges referred to under *c*.
- e is an iron hoop around the top of the tank, but $\frac{1}{4}$ in. above it, to furnish a rest on which the arm *b* slides.
- f is a pin fastened through the center of the arm *b*, which drops into a hole bored in the wooden filler *F*, the center of rotation for the arm.
- F is the wooden filler in center of the tank to occupy space and reduce the holding capacity of pulp, thereby obviating the necessity of fine grinding a larger sample of dry pulp.
- g is a handle on the arm *b* by which the arm is revolved by hand to skim off the mineral-laden froth.
- h is a baffle-board to intercept the flow of froth around in the mixing circle and deflect it outside into the box *o*.
- i are eye-bolts by which transfer pipes *a* are fastened in place.
- j is the reducer fitting at the intake end of the transfer pipes *a*.
- k is a compressed-air pipe nozzle through which the compressed air is introduced into the transfer pipes.
- l is the iron flange into which the compressed-air nozzle *k* is screwed.
- m are lag screws which fasten the filler *F* to the bottom of the tank so as to give it a central position in the tank.
- n is the iron handle for the wooden plug in the outlet pipe *p*, by which this plug is placed or removed.
- o is the receiving box for mineral-laden froth.
- p is the pipe through which mineral-laden froth is discharged.
- q is an outlet in the bottom of the tank through which the treated pulp is discharged.
- r is the pulp level of the charge to be treated.
- s is the layer of mineral-laden froth formed on top of the pulp.
- t is the pulp-filled "mixing circle," within which the pulp is kept in agitation and in which the froth is created and rises mineral-laden to the surface.
- u is a small iron strap clamped across the bottom open-



PLAN

PARRAL EXPERIMENTAL TANK
OIL FLOTATION
Capacity 100 lbs. in 3:1



VERTICAL ELEVATION
THRU. LINE A-A.

ing of the reducer *j*, through the center of which the air nozzle *k* enters and is held in place.

In the laboratory, or at a commercially operating plant, this experimental tank is set on rack or trestle about 18 in. above the floor for convenience in making bottom connections and drawing off the charge.

The adaptation of Parral tanks for oil flotation in commercial operation is the subject of a pamphlet recently issued by the Parral System of Tank Agitation (Mr. Bernard MacDonald, manager), I. W. Hellman Building, Los Angeles, Cal.

Selenium.—The demand for selenium in 1915 fell off considerably, owing to absence of buying orders for railroad signal lamps and the curtailment of foreign export. The copper refineries have decreased their production somewhat, and in some cases the method of production has been changed. The price has ranged from \$2 to \$5 per pound.

Industrial Notes

Hearing on Dyestuffs Tariff.—Chairman Kitchen announced on Jan. 10 that the House Ways and Means Committee would begin hearings Jan. 14 on Representative Hill's bill proposing protective import duties on dyestuffs and certain chemicals, with a view to protecting and building up a domestic dyestuff industry.

Messrs. Eimer and Amend will erect a new building adjoining their present one at Eighteenth Street and Third Avenue, New York, to take care of their increasing business.

The Supplee-Biddle Hardware Company, Philadelphia, Pa., has increased the capacity of its Monel metal-casting foundry, to take care of its increased business.

The Wilson-Maculen Company of New York, pyrometer manufacturers, have moved to their new factory at Wales Avenue and East 142nd Street. The office and laboratory are also at the new address.

The H. W. Caldwell & Son Co. of Chicago announces the opening, on Jan. 1, 1916, of a sales and engineering office at 711 Main Street, Dallas, Tex., in charge of Mr. J. C. Van Arsdell.

The Edison Portland Cement Company, whose factory is at Stewartville, N. J., will resume operations in the spring. New machinery and improvements to cost \$200,000 have been authorized and will be completed by that time.

Disc Crushers.—Chalmers & Williams of Chicago Heights, Ill., have furnished one 48-in. Symons disc crusher to the Nevada Consolidated Copper Co. and one to the American Smelting & Refining Company at Hayden, Arizona.

The Armstrong Cork Company of Pittsburgh, Pa., has issued another edition of their corkboard catalog entitled "Nonpareil Corkboard Insulation." This book contains much information of value to anyone interested in heat insulating materials for low and moderate temperatures.

Duriron.—The Duriron Castings Co. of New York City has sent us a very attractive little concentrating dish, made of acid-proof duriron, which may be used as an ash receiver, but on the desk of chemical and metallurgical engineers will undoubtedly excite the curiosity of the owner to try it out as to the claims made for the non-corrosibility of duriron under trying conditions.

The new plant of the **Federal Dyestuff & Chemical Co.** at Kingsport, Tenn., is being pushed to completion as rapidly as possible. A site of 200 acres was donated by the Kingsport Development Co.

The November number of **The Labor Saver**, the little booklet issued by the Stephens-Adamson Mfg. Co. of Aurora, Ill., contains some interesting illustrated descriptions of coal handling machinery.

The Wellman-Seaver-Morgan Company, Cleveland, Ohio, has received contracts for four gas producers, together with a producer building and coal and ash-handling machinery for the Imperial Steel Works of Japan.

An **Industrial Exposition** will be held in Dayton, Ohio, Jan. 14 to 22, 1916. The exhibit will be held in the excellent new Delco building of the Dayton Engineering Laboratories Company. There will be ten exhibits, including automobiles, machinery, building materials, electricity, flowers, food, mercantile, advertising, business appliances and municipal shows. The object is to display goods made in Dayton.

Increasing Use of Aluminium.—The Nordyke & Macmon Co. of Indianapolis created a sensation at the

recent Automobile Show in New York by showing a car with engine cylinders and crank case cast integral in one light, sturdy block of aluminum. Aluminum pistons are also used. The extensive use of aluminum castings in this car has resulted in a reduction of weight by 1000 lb.

Substitution of Copper for Aluminium.—Some companies have found it profitable to substitute copper wire for aluminum conductors in their transmission lines, in view of the high price which can be obtained for the aluminum.

Aluminium and Bauxite.—Information on the aluminium industry of the United States in 1914 is contained in Bulletin No. 7, Part 1, of the Mineral Resources of the United States. Production statistics, consumption, imports, uses and methods of manufacture are included. The author is Mr. W. C. Phalen.

The Donora zinc plant of the American Steel & Wire Co. commenced producing sulphuric acid on Dec. 23. When the entire plant is completed it will contain ten furnaces with an output of 40,000 tons of spelter and 100,000 tons of commercial sulphuric acid per year. The acid plant is a three-unit plant, each unit comprising a tower, chamber and two roasting furnaces.

The Davison Chemical Corporation has been organized to take over all of the assets of the Davison Chemical Company of Baltimore, Md., large makers of sulphuric acid and fertilizer. Additions to the plant are being made which will give it an output of 300,000 tons of acid per annum. An acidulating plant is also under construction which will have a capacity of 300,000 tons of acid phosphate per annum. It is expected that this plant will be completed by the middle of next summer.

The Morse Bros. Machinery & Supply Co. have purchased the entire plant of the Kuenzel Process Smelter located at Buena Vista, Colo., and will dismantle and ship to Denver. This plant was never completed and only parts of it were in operation at all. A complete power plant of high pressure boilers, engines, blowers, compressors, crushing plant, machine shop. Fire and boiler feed pumps, shafting elevators, etc.

The Mineral Products Corporation, which started at the end of 1915 the successful production of potash from Utah alunite, is so much pleased with the results so far obtained that it intends to double the capacity of its Marysville plant in the near future. It is expected that the contract for this extension will be let to Westinghouse, Church, Kerr & Co. Mr. Howard F. Chappell is the president of the company. The vice-presidents are Mr. C. H. Macdowell, representing the Armour interests, and Mr. S. J. Jennings, representing the United States Smelting Co., while Mr. R. B. Forsythe is general manager of the mine and the plant.

The Buffalo Potash and Cement Corporation has been formed to erect a plant with a capacity of 20 tons of potassium salts per day with a simultaneous daily production of 750 barrels of cement. It is expected that the first unit of the plant, producing 10 tons of potassium salts per day, will be in operation in April, 1916. The Ruggles-Coles Engineering Company has undertaken the construction of the plant and supervision of installation. Mr. William B. Ruggles is a member of the board of directors of the Buffalo Potash & Cement Corporation.

To Authorize Exploration.—A bill designed to authorize exploration for coal, phosphate, oil, gas, potassium and sodium in public lands, and to provide for its disposition, will come before the House this week. The bill is a committee measure.

Mineral Production.—The value of the mineral production of the United States in 1914, according to the

Geological Survey, was \$2,114,946,024, being exceeded only by 1913 and 1912.

Sulphuric Acid in 1915.—The estimated production for 1915 of 50, 60 and 66-deg. acid is 4,007,000 tons, expressed in terms of 50-deg. strength, according to the Geological Survey. In addition there was a production of nearly 49,000 tons of fuming acid and oleum. These figures include by-product acid produced at copper and zinc smelters amounting to 952,000 tons of 60-deg. acid. This is an increase of 25 per cent over 1914. The prices were much higher than in 1914, and consequently the total value will be far in excess of the previous year.

Large Petroleum Production in 1915.—According to the Geological Survey the marketed production of petroleum in the United States in 1915 approximated 267,400,000 barrels, and the total yield approximated 291,400,000 barrels, about 24,000,000 barrels being placed in field storage. The increase is accounted for by the continued output of oil in large quantities from Oklahoma, Texas and Louisiana.

Increased Arsenic Production.—The estimated production of white arsenic for the year 1915, according to the Geological Survey, was 5,195 tons (of 2000 lb.), with a value at the smelter of 2 cents a pound. The estimate is based on the known production for the first ten months and the probable output for November and December. This output is an increase of more than 11 per cent over the 1914 production and 65 per cent over the 1913 production. The demand is far below the possible production, which could probably be made three or four times the present output if prices were sufficiently high.

Transvaal Gold Production.—The number of companies reporting to the Transvaal Chamber of Mines in August, 1915, was 63. The total quantity of ore milled during that period was 2,478,267 tons. There were 9955 stamps in operation, with an average duty of 9.42 tons per 24 hr. Tube-mills in commission numbered 321. The yield for the month was 778,763 fine ounces gold. The tonnage treated and the yield of fine gold are the largest recorded this year.

Iron and Steel in Canada.—Bulletin 349 has been issued by the Department of Mines, Canada, containing information on Canadian production of iron and steel in 1914.

Electrothermic Smelting of Iron Ores in Sweden is the title of an illustrated bulletin, No. 344, just issued by Dr. Alfred Stansfield for the Canadian Department of Mines, Ottawa, Canada.

Copper in Arizona.—Market conditions resulting from the European war lessened the output of copper in Arizona from 407,923,402 lb. in 1913 to 393,017,400 lb. in 1914, according to the U. S. Geological Survey. Nevertheless, Arizona continued to be the leading copper-producing State.

Coal Mining in Illinois.—The growth of the industry in this State, the development of methods of mining and the present mining practice and markets are given in Bulletin 13, published by the Illinois Coal Mining Investigations, Urbana, Ill. The author is Mr. S. O. Andros.

Platinum in Spain.—The discovery of platinum in Spain was announced in an address made by Professor Orueta before the Society of Civil Engineers of Spain. Professor Orueta made an examination of the Ronda Mountain for the Institute Geologico (Geological Society) and found rich and extensive deposits. A Royal Decree has been announced reserving this district within certain boundaries to the State for a limited period for scientific investigation.

Mineral Resources of California.—The California State Mining Bureau is preparing a new general report of all of the mineral resources of California, under the direction of State Mineralogist Fletcher Hamilton. Instead of delaying publication until the entire area of the State has been covered the reports are being issued as advance chapters, by groups of adjacent counties, as soon as complete by the field men. All mines, quarries, mineral springs, cement mills and other plants handling mineral products are listed and described. The chapters already issued may be obtained upon application to the State Mining Bureau, Ferry Building, San Francisco.

Hydroelectric Development and Nitrogen.—In a talk recently given before the Commercial Club of Boise, Idaho, Mr. Henry J. Pierce of Seattle, Wash., said that the United States imported during 1913, about 625,000 tons of Chilean nitrate, valued at \$21,000,000, upon which the Chilean export duty was 60 per cent. The United States thus paid to the Chilean government \$12,600,000, which may be considered merely a part of the amount which the people of the United States pay for its policy of water-power stagnation. In other words, the people of this country would be quite as well off as they now are if they granted a subsidy or bonus of \$12,600,000 per annum for the establishment of the water-power nitrogen industry in the United States. In Europe over 1,200,000 water-hp. is used.

Obituary

Richard Henry Lee, superintendent of the Lebanon blast furnaces of the Pennsylvania Steel Company, died suddenly on Dec. 8, 1915. Mr. Lee received his education at Lehigh University, and upon leaving there was placed in charge of the cold blast charcoal furnaces of the Logan Iron & Steel Company at Burnham and Greenwood Furnace, Pa. He became general superintendent of the Logan company in 1891, and was assistant general superintendent of the Colorado Fuel & Iron Company from 1899-1903. He was connected with a number of other companies, and in 1906 became associated with the Pennsylvania Steel Company, taking charge of the Lebanon furnaces. Mr. Lee was also consulting engineer for the American Manganese Manufacturing Company in 1914-1915. He was noted for giving freely to others the benefit of his technical knowledge, and he was a frequent contributor to the American Institute of Mining Engineers and to the technical press. His last contribution to technical literature was published in the issue of Dec. 1, 1915, of METALLURGICAL AND CHEMICAL ENGINEERING (page 882), when he discussed the use of wet ores in charcoal blast furnaces. He made many warm friends in his numerous positions. He was a member of the American Iron and Steel Institute, the American Institute of Mining Engineers, and the Engineers' Society of Western Pennsylvania.

T. L. Willson, who took a prominent part in the early development of the calcium-carbide industry, is dead at New York City. Mr. Willson began his engineering work in 1880, when he constructed an arc outfit used for street lighting at Hamilton Ont., Canada. While the principal work which led to the foundation of the calcium-carbide industry, and in which he very actively participated, was done in North Carolina, Mr. Willson lived later many years in Canada and was interested in many undertakings besides calcium-carbide and acetylene. Until two years ago Mr. Willson was president of the International Marine Signal Company. Since that time he had devoted his entire attention to a new process for producing nitrogenous fertilizers from the air.

Personal

Mr. Edgar Baruch, chairman of the Southern California Section of the American Chemical Society, was re-elected a director of the Chamber of Mines and Oil of Los Angeles, Cal., at the annual meeting on Dec. 16.

Mr. Charles A. Chase has moved his Denver office from the First National Bank Building to 812 Cooper Building.

Prof. G. H. Clevenger of Leland Stanford, Jr., University attended the Pan-American Congress in Washington, and before his return to the Pacific Coast he was a few days in New York City.

Mr. E. H. Hamilton, formerly manager of the Virginia Smelting Co., has become consulting metallurgist to the Consolidated Mining and Smelting Co., Ltd.

Mr. Elwood Hendrick, who will be remembered as secretary and manager of the Albany Aniline and Chemical Works back in the early eighties, but more recently as editor of *The Percolator* and as vice-president of the Chemists' Club for several years, has left Wall Street. He has retired from his connection with Messrs. Denny, Pomroy & Co. of the New York Stock Exchange, with a view to addressing himself to literary work. We are very glad, indeed, to state that Mr. Hendrick has accepted the invitation to become a regular contributor to this journal.

Mr. James M. Hyde expects to move from San Francisco to Denver within a month, and make his future headquarters in the latter city.

Mr. R. E. Howe, formerly chief chemist for the Anaconda Copper Mining Co., has been promoted to be assistant superintendent of the converter department. He is succeeded by the former assistant chemist, Pierce Barker.

Dr. R. A. Kocher, chief chemist of the Pacific Chemical Wood Products Co. of San Francisco, was recently in New York City and the Eastern cities.

Mr. J. H. Mackenzie will become president of the Alaska-Treadwell on Jan. 1. He will be succeeded as consulting engineer by P. R. Bradley, who has been general superintendent. The latter position will now be filled by Russell Wayland.

Mr. Stuart B. Marshall, who has been connected with the Dunbar Furnace Company for 21 years, has severed his connection with that company to take charge of the property of the Aluminum Company of America at Whitney, N. C. This plant was recently acquired from the Southern Aluminum Co. and the works and immense dams are being completed. A new town, to be called Badin, is also under construction.

Mr. Thomas C. Oliver, manager of the Chemical Construction Co., Charlotte, N. C., was married on Jan. 5 to Miss Catherine Hill of Austin, Tex. Mr. Oliver spent some years as a mining engineer in the West before becoming associated with the Chemical Construction Co.

Mr. Thomas T. Read, who a few years ago, as the New York editorial representative of the *Mining Press* and as the very active secretary of the New York Section of the American Institute of Mining Engineers, made many friends in New York, has joined the staff of the New Jersey Zinc Co. in New York City.

Mr. R. W. Schultz, who as mill superintendent for the Mond Nickel Co., Ltd., of Conniston, Ontario, has had charge of extensive experimenting in the concentration of the copper-nickel ores of the Sudbury district, has resigned, having completed this work with entire success. He is spending several weeks at his home in Ravenna, Ohio.

Mr. B. B. Thayer expects to sail for Chile about Jan. 15, where he will spend about a month.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Aqueous Bath Apparatus

(Continued)

384,806, June 19, 1888, William W. White of Waterbury, Conn., assignor to Rogers & Brothers of same place.

Relates to a rack for supporting such articles as spoons, forks, etc., that are subjected to unequal wear, and require extra thick deposits on certain spots. The rack consists of two parallel rods suitably supported, and a third rod rotatable about its longitudinal axis, the third rod is supported upon the supports of the first rods. The third rod is provided with a plurality of spaced transverse flat wire springs the ends of which are connected by a chain. The third rod with springs and chain are folded back, the spoons, etc., placed across the first parallel rods so as to lie between the flat springs, the third rod and springs are then folded down and secured so that the chain engages and holds each spoon, etc., in place, and the frame supported over the plating tank so that the spots to be plated extra heavy will receive the desired deposit. The spoons, etc., are then removed and plated entirely. Or the plating process may be reversed, the spot plating being applied last.

414,860, Nov. 12, 1889, William A. Dunlap of Pittsburgh, Pa.

Relates to racks for supporting articles to be electroplated. The rack consists of a clamp made of a continuous rod or stiff wire, bent U-shape with preferably a coil at the bend. The long parallel arms are provided with a plurality of transverse rods projecting toward each other, which support an article to be plated. The arms are held together by a link or clasp. It is especially designed for such articles as screw-threaded caps for tin boxes.

441,892, Dec. 2, 1890, William J. Possons of Cleveland, Ohio, assignor to The Brush Electric Company of same place.

Relates to clamps for holding arc light carbons while being electroplated. The clamp may be described as a tubular clamp divided longitudinally into two parts which are hinged together, and which are provided with a spring to force the jaws into engagement with the carbon. The clamp is provided with an insulated metal contact and contact spring which electrically cuts out a clamp when not supporting a carbon, thereby preventing an open circuit among carbons which are connected in series. The patent refers to a copending application which became patent No. 441,894.

441,894, Dec. 2, 1890, William J. Possons of Cleveland, Ohio, assignor to The Brush Electric Company of same place.

Relates to an apparatus for distributing, supporting and electroplating a large number of arc light carbons at one operation. The carbons are quickly sorted on a subdivided tray, which upon inverting, discharges the carbons into a bank of tubular holders, the latter being quickly filled. A plurality of carbon clamps, such as described in his patent 441,892, are mounted upon a support, and placed over the projecting ends of the carbons in the bank of tubular holders, whereby the carbons are taken up by the clamps. The clamped carbons are next immersed in a tray of separate electrolytic cells wherein they are electroplated. The patent should be consulted for details.

459,838, Sept. 22, 1891, Edward S. Hayden of Waterbury, Conn.

Relates to a siphon to automatically maintain the level of the electrolyte in a tank, constant. It consists of a U-tube having one arm longer than the other, and an opening in the outer wall of the bend opposite the short arm. The siphon is secured in the side wall of the tank, with the long arm outside, in such a manner that the small opening is below the top of the tank. If the tank became too full, the excess liquid would cover the small hole, and the siphon would thereupon automatically remove the excess solution. After the hole became uncovered, the siphon would act as an overflow spout until the level of the solution reached that of the lower wall of the bend.

469,538, Feb. 23, 1892, Alexander D. Buchanan of Long Island City, N. Y.

Relates to a process of and apparatus for electroplating the iron hulls of vessels. The vessel is floated into a dock and over a collapsible flexible envelop which has been dropped to the floor of the dock. The vessel is supported upon a suitable keel-base, and by side braces, and is then thoroughly cleaned by scratch brushes, etc. A pickle of weak acid is then supplied to the flexible envelop which is raised to surround the ship, and the cleaning process completed. The pickle is then withdrawn and an alkaline copper plating solution supplied to the envelop, the iron hull being connected as cathode, and using an anode of copper links connected together, each link supporting one or more large insulating washers. As the level of the electrolyte in the envelop is raised, workmen scrape the iron just above the level to insure a deposit of copper taking place. After a deposit with alkaline electrolyte has been effected the ordinary copper sulphate bath is substituted.

479,557, July 26, 1892, Edward A. Clark of Boston, Mass.

Is for a toy consisting of a small electroplating outfit, made up of two small cells of battery in a case, the latter supporting a cell for the electrolyte. Binding posts are connected to the battery, to which wires for the anode and cathode may be connected.

496,597, May 2, 1893, Seth C. Catlin of Bloomfield, N. J., assignor to Emma F. Catlin of same place.

Relates to an apparatus for supporting articles to be electroplated, and consists of two wooden frames hinged together, preferably with rawhide, each frame being covered with a layer of muslin or canvas, so that the articles to be plated are inclosed therein. A number of hooks within each frame electrically connected to outer suspension hooks, provide means to support the articles.

497,129, May 9, 1893, Albert Roper Reams of Elmira, Cal.

Relates to a cabinet for holding the electroplating battery, various electrolytes and cleaning solutions, also a lamp or other heating apparatus to suitably heat the necessary liquids. The zinc of the battery is suspended from a pulley and may be raised or lowered as desired to vary the current strength.

498,707, May 30, 1893, Thomas S. Crane of East Orange, N. J.

Relates to an apparatus for coating the iron hulls of vessels, and consists of detachable open-sided flat receptacles for holding the electrolyte, the receptacles being held to the sides of the ship by suitable frames which in turn are held in any desired place by electromagnets. The hull of the ship is electroplated in sections, the joints of the several sections overlapping. The patent should be consulted for details.

501,996, July 25, 1893, Stephen H. Emmens of London, England.

Relates to an apparatus for electro-refining pig iron, and consists of a lead-lined steel tank, in which are placed insulating linings of ebontite, etc., the linings providing receptacles at the bottom to collect anode slimes and cathode powder or flakes. As anodes, the ordinary bars of pig iron, as produced by the foundries, are used. These are suspended by hooks from notched anode bus-bars above the cells on each side. The cathodes consist of a plurality of bars of malleable iron. The electrolyte is a nearly saturated solution of ammonium sulphate, covered with a layer of paraffin oil to prevent oxidation. A voltage of from three to four volts is used, and a current of about one-twentieth of an ampere per square inch of active cathode surface.

Book Reviews

Experimental Organic Chemistry. By James F. Norris, Ph.D. $5\frac{1}{2} \times 8$ in., 215 pages; price, \$1.25 net. New York and London: McGraw-Hill Book Co., Inc.

A skillfully written laboratory guide, which ought to enthrall as well as instruct the student. The directions, cautions and precautions, are minute and accompanied by the reasons—a most gratifying style of scientific writing intended for the instruction of students. The tests and experiments chosen are mostly those concerned with very common organic materials, such as fats, soaps, starches, sugars, etc., and thus the interest of the student is most securely held. The book is admirably conceived and executed.

* * *

Elementary Electricity and Magnetism. By Wm. S. Franklin and Barry MacNutt. 176 pages, 152 illus. Price \$1.25, New York. The Macmillan Company.

This is an elementary work on the fundamental phenomena in electricity and magnetism, presented from the standpoint of electromechanics, and thus concerned more particularly with results than the exact nature of the physical causes. The five chapters deal respectively with the magnetic effects of electric currents, chemical effects of electric currents, heating effects, induced e.m.f., and electric charges and condensers; appended to each chapter are several practical problems, with answers.

This book is essentially for the beginner and is made interesting by frequent happy allusions to the practical or useful aspects of the phenomena described, which are very clearly presented.

* * *

Food Analysis. Typical Methods and the Interpretation of Results. By A. G. Woodman. $8 \times 5\frac{1}{2}$ in., $x + 510$ pages, 107 illustrations. Price, \$3.00 net. New York: McGraw-Hill Book Co., Inc.

One of the books of the International Chemical Series, edited by Professor Talbot of the Massachusetts Institute of Technology, this is written by the associate professor of food analysis at that institution. It is intended for students' use, certain typical foods being selected for analysis, more because of the methods of analysis which they illustrate than because of economic importance. The book is, therefore, not a complete compendium of specific methods of analysis of every important food. Particular emphasis is laid on the interpretation of the analyses so as to judge of the practical values of the foods tested. Three general chapters treat of methods of manipulation, use of the microscope, examination for food colors and preservatives; after these milk, oil, butter, etc., are taken up in separate chapters. It is a practical and valuable book. The fine quality of paper used by the printers is especially commendable, over 500 pages (270 sheets) being only three-quarters of an inch thick, and yet of excellent opacity.

Metallurgical and Chemical Engineering

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Shall the United States Be Self-Contained?

With so large a part of the world at war, even those at peace are beginning to feel unsafe. With passions aroused to fever heat there is no telling in many people's minds when, where and how the powers of wrath may rise against us; and the shocking comparison has been made of the present position of the United States with that of a very respectable old lady who goes out into the night with her hundred dollars safely tucked away in her stocking, little dreaming that even her legs are not immune and that there are prowlers at large who are without a sense of propriety.

This fear of an aggression of this country from the outside may or may not be purely psychological; its basis of reality may or may not be congruous to the intensity of the unsafe feeling. Yet the fact remains that the industries of this country while in peace with the outside world have been hit hard in many points by the European war, and the further eminently significant fact remains that those points where the country has been hit hardest are also the very points where it would be most vulnerable in case of war. For an army and a navy are useless without the means to maintain them, and the means consist largely in the self-containedness to meet a situation of war—and this very self-containedness has now been found wanting while this country is at peace. Time was when bows and arrows and swords and shields were the chief equipment of men at arms. At present without a great and complete chemical and metallurgical industry that supports itself in times of peace and can switch over to making war materials when called upon to do so, a nation is vulnerable in war and unprepared for peace. Strange it is, but true, that the making of dye-stuffs and of munitions of war are closely interlocked.

It is fair to say that upon the readers of METALLURGICAL and CHEMICAL ENGINEERING a large part of the ability of this country to defend itself rests. Without highly and completely developed chemical and metallurgical industries neither the army nor the navy could hold its own if we were attacked. Bearing in mind all that has been said of that phase of economics which has to do with the taxation of imports, the facts remain that as things are, the self-containedness of this country is greatly dependent upon these industries, and also that, as things are, these industries cannot hold in this country if no import duties are applied. This does not mean that everything chemical and metallurgical should be protected and that manufacturers should be allowed to write their ambitions for profit into the revenue statutes. This would beget as great an evil as the other extreme.

One of the difficulties of the tariff in the past has been that we have had to treat it as though it were a case in court and but one of only two solutions of its many problems were possible—to determine whether it be generally high or generally low. This seems about all that we have been able to do. The congressman we have voted for may have been familiar with our affairs and anxious to help us, but has had little power to do so. He took his place at his desk like a good little boy at school and voted for the party leader as speaker of the House. The speaker named the committees and allotted membership in each—according to geography. If manufacturers were in trouble at their works, and needed an engineer to help them out, they would not want for that purpose a lawyer from a distant state, selected for geographical reasons. And yet that is about as near as they have been able to reach the question what import duty the Government should charge on the merchandise that they produce. The Congressman's advice might have been good in a case at court, but he has been a rare bird indeed if he could get the chemical situation into his head. It was not his fault: in minor part it was due to his lack of time and training. In major part it was the manufacturer's fault.

When a tariff bill has been introduced, manufacturers—from the chemical and metallurgical fields as well as from others—have been likely to flock to Washington and crowd over each other and lobby and interview and appear at hearings and claim all that they dared ask for. The members of the Committee on Ways and Means have usually been helpless. They could not have heard all that was offered them if they had had ears all over their heads in the place of hair. And if they had had this monstrous endowment they could not have remembered what they heard. And if they could have remembered it they could not have correlated it and brought it into form and into the semblance of truth. For in the past all the time the manufacturers have been contradicting each other. The one using the finished product of another as one of his raw materials wanted that product free. The man making it wanted a dollar a pound duty imposed, but he wanted his raw materials, the intermediates, free. The intermediate man made a similar plea for his product and the man back of him did likewise, all uttering the same cry, but calling for a different law. This is somewhat overdrawn, nevertheless it is a caricature of something that has been real. No wonder it is said congressmen have taken to drink. And the result of it all has been that the United States has never had a good, well constructed, suitable tariff law.

Yet two bright rays fall into this dark-in-dark picture. It is a picture of the past. The future may be different. In its present troubles this country has learned something. The manufacturers have learned something, and the Government has learned something. How much the manufacturers have learned became manifest at the hearings before the House of Representatives Committee on Ways and Means on the Hill

bill for a dyestuff tariff last month, of which a full account may be found on page 125 of the present issue. It was not a series of pleadings of everyone for his own pocket. There was pretty general unanimity of opinion that the whole matter must be considered from a higher plane, in a co-ordinated manner, with this one principal leitmotiv: that this country shall be self-contained. For the part it has played in crystallizing this sentiment, the Chemical and Dyestuff Committee of the New York Section of the American Chemical Society and its chairman, Dr. Hesse, as well as the president of the national society, Dr. Herty, really deserve great credit.

The other ray of hope—and possibly the greater wonder of the two—is, of course, the reported conversion of the Administration to the necessity of a non-partisan permanent tariff commission. There was once such a commission. It went out after the Democrats came in. If it now comes back through the Democrats it is hard to see how any party can ever afford to let it go out again. There is good reason for rejoicing and to the Administration high praise is due for having the courage of freshly acquired conviction. But for the representatives of the chemical industries to think that now their task is ended would be a frightful and fatal mistake. The good work begun by the Chemical and Dyestuff Committee of the New York section of the American Chemical Society and by others needs to be continued, broadened, strengthened, intensified. The tariff commission—if it comes into existence—will need all the help and advice it can get from those thoroughly familiar with the technical details of all the industries. Let the chemical and metallurgical industries be in the front rank to render freely such service in co-operation.

And yet when all is done that is humanly possible for the chemists to do, more remains to be done. Dr. Baekeland was right when he said in his Perkin medal address (published in full on page 151 of this issue) that if we turn our present unparalleled chances of success for creating a great American chemical industry into a gigantic fiasco, the whole blame should not be placed on our chemists. Let Dr. Baekeland's address be read—broadcast throughout the land—by our business men, captains of industry, and lawmakers. Let them understand that American chemists are striving not merely for themselves but for the self-containedness of the American nation.

The Future of Steel Prices

In the past dozen years there have been three high levels in steel prices, in 1907, at the close of 1909, and at the close of 1912. The present average of finished steel prices, not for prompt shipment but for shipment at mill convenience, is about \$2 a net ton above the first high point, \$6 to \$7 above the second and about \$8 above the third. It required a period of about two years, with continued heavy demand and mills working at high pressure, to develop the high level of 1907. The present level has been reached in thirteen months, and two-thirds of the total advance has occurred in the past four months of the thirteen.

Clearly the steel market has passed entirely beyond its ordinary bounds, as established by the precedents of a dozen years, and yet prices still show a rising tendency. The natural inference is that eventually the readjustment will come, that prices will fall. Meanwhile, however, new conditions may be established whereby prices may not fall to the preceding low levels. It is certainly important to consider the probable bearing of such new conditions as we see being established at present, or can foresee as likely to develop.

In the iron and steel industry great changes in processes of manufacture occur in a few years. Truly wonderful economies have been introduced, but these do not show in prices quoted in money. In terms of money, steel sold at its lowest prices in 1897 and 1898. In terms of mental and manual effort expended and intrinsic value of raw material and equipment used, steel is to-day produced at very much lower cost than at that time. For instance, wages per hour are very much higher while in addition the mental and manual effort per hour of the workman is undoubtedly decidedly less. Again, the intrinsic value of the ore used is very much less than formerly, the iron content being lower and the material to be fluxed off, involving additional consumption of limestone and coke, is much greater. For another of many illustrations that could be given, the equipment used, while costing much more, is produced by the builders at much lower cost, measured in terms of mental and manual effort expended in its building, and in its efficiency for the purpose, than formerly. If the iron and steel industry were given to-day the same raw materials and the same wage rates and labor performance as in 1897, combined with present practice and equipment produced with the same low-priced labor, it would be able with such a combination to sell steel at astonishingly low prices.

While improvement in processes and equipment is bound to continue, it cannot be expected that progress can be so rapid in future as in the earlier years. The curve representing cost of production in terms of effort expended and consumption of material cannot become tangent to the line of perfection, but it has some of the characteristics of an asymptote. It seems reasonable to conclude therefore that the future of steel prices, measured in terms of money, will hinge more upon economic conditions than upon technical progress.

Sweeping changes have been brought about in economic conditions by the war, and probably still greater changes are to occur in the future. For decades the iron and steel industry has been supplied with labor chiefly through immigration. There have been successive changes in the source of the immigration, until in recent years it has been chiefly Croatian, Slavonian, Italian, Magyar, Polish, Roumanian, Russian, Ruthenian and Slovak. Prior to the war there had been noted a tendency in this immigration to decrease relative to the requirements of the industry. Economic conditions resulting caused wages in the iron and steel industry to rise somewhat more rapidly than the general wage level of the country. Early in 1913 the industry made a general wage advance at a time when there was no corre-

sponding general advance in wages. The war has caused immigration almost to cease, and this change has affected the iron industry much more than it has affected industries in general. The net change in the population of the United States occasioned by people entering and leaving the country was an increase of 754,205 in the fiscal year 1913 and an increase of 687,065 in the fiscal year 1914, making an average increase of 60,000 per month. From July 1, 1914, to Dec. 1, 1915, the net increase was 124,033, or 7300 per month. Thus the war has been causing a deficiency to accumulate in our population at the rate of 52,700 per month or 630,000 per year, and this loss bears much more upon the iron and steel industry than it does upon industries in general. At the present time a general advance in wages is being made in the iron and steel industry, at a time when wages in industries as a whole are not being specifically advanced.

One can scarcely conjecture what will occur with respect to immigration when the war closes. One does not even know what the conditions will be, how seriously territory has been or will be ravaged, what effort would be required to restore it, and what power there will be to make the effort. The balance of probability appears to be that there will be no large immigration, or at any rate such as would make up for the deficiency now accumulating and for the industrial expansion now in progress in the United States. The steel industry, therefore, seems to face for the future distinctly higher wage rates, relative to those which may prevail in industries generally, than in the past. Measured in commodity values steel should, therefore, be expected to sell at higher rates than in the past.

We are accustomed to seeing commodity values and security values move together. When credit is readily obtained the value of both securities and commodities tends to advance, and when credit conditions are strained the reverse occurs. The war tends to divorce these trends from each other. It occasions both a great destruction of commodities and a great deal of borrowing. At the close of the war the demand for commodities will be out of proportion to the ability to borrow. Commodities will tend to be higher in price than normal relative to the value of securities. The demand for commodities that can be paid for in current effort, pay as you go, will be greater than the demand for commodities that are to be paid for with credit, by the flotation of securities. Steel falls more in the latter category than in the former, and in this respect it will be at a disadvantage. Man will have to make the effort to build up a greater credit structure than has ever existed before. How successful the effort may be remains to be seen, but there will be the foundation that has been lacking for many years, the certainty that there will not be a great war for a long time at least. For many years past a distinct element of timidity has been observable in capital abroad, ascribed openly to the fear of a continental war. If the credit structure can be built up, then all the elements will be present for higher prices for steel, relative to commodities in general, than have prevailed hitherto.

Reader's Views and Comments

Hydrometallurgy of Zinc and Lead

Electrolytic Zinc at Bully Hill

To the Editor of Metallurgical & Chemical Engineering:

SIR:—I wish to be allowed to correct what seem to me some slightly inaccurate statements of Messrs. Lyon, Ralston and Cullen in your issue of Jan. 1, page 30, in their article on "Hydrometallurgy of Zinc and Lead," regarding zinc processes, more especially as practised at Bully Hill, Cal.

Some two years of conscientious effort were expended in the development of the zinc hydrate process described, and excellent zinc cathodes were made during a fair share of this period.

It also appeared that zinc could be made by this process at a cost which would make commercially possible the production of from 10 to 20 tons of zinc per day at Bully Hill.

Both the Bully Hill Company and the General Electric Company, the owners of the Bully Hill property, however, were quite as much interested in the development of a generally and widely applicable process, and they finally concluded that the zinc hydrate process could not compete to advantage in the Montana, Utah, Idaho district, e. g., which the writer considered the most promising one in the country, and other important districts.

As a result, the zinc hydrate process was set aside for the time, and substantially a method that was earlier tried with some success, but with modifications, was reverted to, viz., direct electrolysis of zinc sulphate with regeneration of acid, and this has been since continued.

The revised process was planned out in October and November, 1914, was put in practice in March, 1915, and has been producing 300 to 400 lb. of zinc per day most of the time since then—practically the full capacity of the experimental plant.

During this period the only raw materials entering the plant, aside from materials of construction, etc., have been fuel oil for roasting and melting zinc. More than enough acid is fixed in roasting to supply losses, and chemical reagents have been used for analytical purposes only.

The process, as it stands, is partly old, but was never before made commercial. The ways and means, mechanical and other, are perhaps new in detail. Certain very valuable results of the work are a wealth of collected data, intended to fix the approximate limits, as nearly as may be, between which profits can be produced under somewhat varying conditions with different zinc ores.

The authors of the article which attracted my attention state that the electrochemical zinc plant is extraordinarily expensive as an investment, as compared with the older retort process plant.

This is only true, I think, in any or the usual case, as the primary power station may be taken as a part of the electrochemical plant.

A completely equipped electrochemical zinc plant of 200 tons zinc per day capacity at Butte, Mont., including substation (but not primary generating plant), offices, laboratories, repair shops, etc., would cost, I estimate, between \$2,400,000 and \$2,600,000. These figures were



FIG. 1—OUTPUT OF BULLY HILL ELECTROLYTIC ZINC FOR TWO OR THREE WEEKS

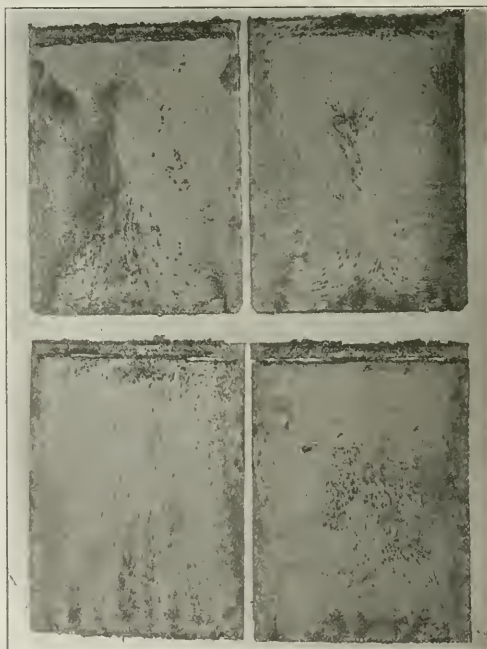


FIG. 2—STATIONARY CATHODE DEPOSITS OF ELECTROLYTIC ZINC, 24 IN. X 36 IN.

worked out directly in considering the Butte & Superior Copper Company's property.

An equivalent retort process plant, including its roasters, pottery, etc., but not a sulphuric acid plant, would evidently cost \$2,800,000 to \$3,200,000, depending upon its location.

An electrochemical plant producing 10 tons of zinc per day would cost \$200,000 to \$300,000, depending upon location, etc. The former figure would cover a zinc plant auxiliary to a going smelter—the latter would be more nearly approached by a plant dependent upon its own repair shops, offices, laboratories, etc.—particularly if the roaster gases required special treatment before being released.

The writer does not believe that a retort plant of 10 tons of zinc per day capacity could be put in operation for particularly less than these figures. The operating costs would most evidently mount more rapidly with a decreasing production rate in the case of a retort plant than in the case of the electrochemical plant.

Messrs. Lyon, Ralston and Cullen may also mislead a little, I fear, when they state that "extraordinarily cheap" power is essential. Cheap power is likely to be essential, it is true, especially where no higher than a 60-per cent zinc concentrate is treated.

Butte-Superior concentrates, 55 per cent zinc, could easily carry a power rate of \$25 to \$30 per horsepower-year. Zinc ores with 25 per cent to 45 per cent zinc could carry somewhat higher power rates so long as the retort process continued to fix the value of zinc ores or zinc concentrates delivered to the electrochemical plant.

These power rates exceed American Niagara rates by 40 per cent to 65 per cent, and exceed Norwegian rates by some hundreds per cent.

What other electrochemical industry could afford \$25 to \$30 per horsepower-year in Montana in normal times and with normal Montana labor costs?

Ferrosilicon could not, except with 50 per cent alloy selling consistently at \$70 or better; calcium carbide might with a developed Western market; atmospheric

TABLE I—COSTS PER TON OF ZINC

	Retort Process, Oklahoma	Electro- chemical Process Butte, Montana
Plant capacity tons zinc per day	200	200
Cost per ton zinc:		
Salaries	\$1.25	\$0.93
Labor	11.30 (\$1.75 and \$2)	6.00 (\$3.50)
Gas at 4c.	2.93	
Coal at \$2.	1.67	
Power at \$26 hp. yr.	0.25	14.65
Clay	0.63	
Repairs and sundries	1.04	4.14
Fixed capital charges 16½ per cent first cost	\$18.82	\$25.72
	6.36	5.70
Total treatment cost	25.18	31.42
Freight on concentrate to Oklahoma	16.62	0.00
Freight to St. Louis on zinc	\$41.80	\$41.80
Freight to New York on zinc	7.20	2.60
		10.00
Treatment cost and freight per ton zinc:		
F.o.b. St. Louis		
F.o.b. New York	49.00	44.40
		41.42
Above figures neglect mining and milling costs to produce concentrates; also neglect relative recoveries of zinc values which would be:		
For retort process, say	87.0%	
For electrochemical process		
Correcting for relative recoveries, the relative treatment and freight costs on above basis would be about:		
For St. Louis delivery	\$44.40	\$37.06
For New York delivery	\$49.00	\$38.06
Equivalent cost per lb. zinc	2.45c.	2.22c.
		1.903c.
		1.853c.
Net value of silver, lead, copper in residues from Butte-Superior concentrate (26 oz. Ag.)	\$7.20	\$22.70

nitrogen fixation could not; aluminium could, were there any necessity for it.

That electrolytic zinc is commercially possible in Montana is indicated by the estimates in Table I, referred to above, made two years ago, and only revised slightly in the light of later knowledge and develop-

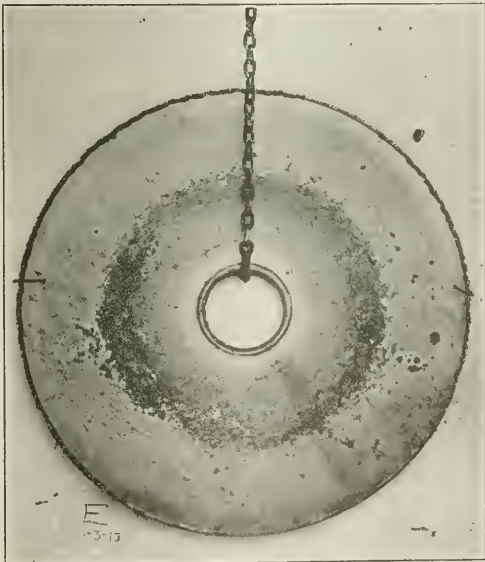


FIG. 3—ROTATING CATHODE DEPOSIT, 320 LB. (4 FT. DIAMETER, 1½ TO 2 R.P.M.)

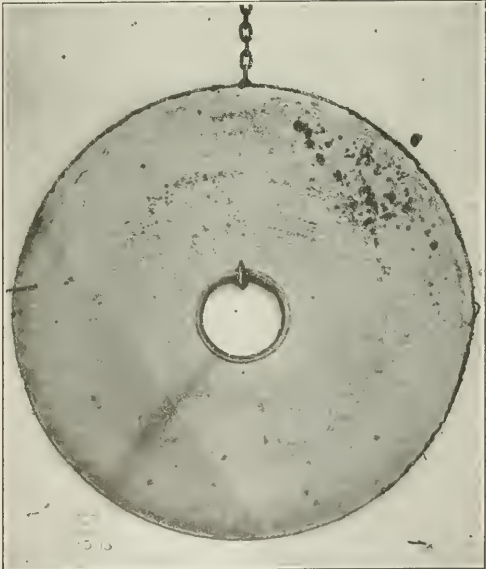


FIG. 4—VIEW OF THE REVERSE SIDE OF THE SAME ROTATING CATHODE

ments. They indicate to the writer that it would be economically profitable to ship the Butte-Superior Company's product to market from Montana as spelter rather than to Oklahoma as concentrates.

TABLE II—ANALYSES

	Bully Hill Ore	Bully Hill Zinc
Zn	29.0	99.98
Fe	15.0	.0053
Cu	2.5	.0050
Cd	0.3	.0010
Pb	tr	tr
Pn	tr	none
S	31.0	.....
SiO ₂	6.0	.....
Al ₂ O ₃	8.0	.....
BaSO ₄	3.0	.....
CaO	2.5	.....
MnO	0.6	.....
MgO	2.8	.....

Herewith are a series of photographs of zinc deposits made at Bully Hill not especially selected; also analysis of Bully Hill representative ore and analysis of electrolytic zinc therefrom.

C. A. HANSEN.

Research Laboratory,
General Electric Co.,
Schenectady, N. Y.

Hydrometallurgy of Lead

To the Editor of *Metallurgical & Chemical Engineering*:

SIR:—In your issue of Jan. 1, under the subhead of "Lead," of an article entitled "Hydrometallurgy of Zinc and Lead in 1915," by Messrs. Lyon, Ralston and Cullen, there is a description of a process for the extraction of lead from its ores by the use of a strong brine. It might appear to many that the development of this method was quite recent, while as a matter of fact it has been familiar to a number of us for some twenty-four years.

During the year 1892, while conducting my metallurgical testing laboratory in San Francisco, I developed a method for the treatment of some of the oxidized ores of the old Willow Creek Mine situated in Washoe County, Nevada. The ore contained about 10 per cent lead, nearly all of which was in the form of sulphate, the remainder being galena. The ore also contained about 10.0 oz. of silver per ton, none of which was soluble in a solution of thiosulphate of soda.

The solution used by me to treat this ore was made by adding 20 lb. of common salt and $\frac{1}{2}$ lb. of copper sulphate to every 100 lb. of water. This solution was placed in small wood vats and heated almost to the boiling point, at which time the dry ore which had been crushed through a 40-mesh screen was added, forming a mixture of about 1 to 1. This mixture was agitated by the injection of steam, which also sustained the temperature.

After agitating for about one hour the mixture of solution and pulp was diluted to about 4 to 1 with the plain hot salt solution without the copper sulphate, and then agitated again for a few minutes, when the pulp was allowed to settle and the clear solution on top drawn off, at which time more plain hot salt solution was added and the operation repeated, and finally giving the settled pulp a displacement wash by gravity with hot fresh water. The hot solution drawn from the vats was passed through cement copper to recover the silver and then through scrap iron to recover the lead and small amount of copper held in solution. The extraction on this ore was over 85 per cent of both the lead and silver.

Experiments were also made on some of the old concentrates which had been lying in the mill for years. They carried quite a percentage of sulphides and arsenic. They were therefore given an oxidizing roast and then treated by the above method with an extraction of only 45 to 50 per cent of the contained lead and silver.

The largest amount of ore that I treated by this method at one time was about 1 ton, and that lot was treated in Salt Lake City in 1900 to demonstrate to a party of men the feasibility of the method for the particular ore mentioned above, all former tests having been made on samples of from 1 oz. to 500 lb.

HENRY R. ELLIS.

Salt Lake City, Utah.

Will Silver Come Back?

To the Editor of *Metallurgical & Chemical Engineering*:

SIR:—An eminent European authority of international standing—Mr. Moreton Frewen—in a recent letter to the writer says:

"I anticipate that when the Bankers, after the War, have come to count its cost and the enormous mass of unconvertible paper that has been issued and most of which will be at a huge discount, they will take immediate steps to secure Open Mints and Free Exchanges for the two metals"—i.e., gold and silver.

In view of the increasing international scramble for the world's limited supply of gold (when compared with the business of the world), and the recent great flow of that metal from Europe to the United States in payment for food, raw materials and war supplies, all indications are that the European countries will, after the war, be absolutely driven by dire necessity to a greater recognition of silver as a money metal, which will have far-reaching effects on the world's trade and commerce and will enhance the market price of silver.

This will necessarily affect the United States as a great silver producer and exporter, and American trade with silver-using countries.

Unfortunately, matters of finance a little out of the usual course too often do not appeal to business men and others absorbed in their own affairs. They do not take the time to understand them and, not understanding them, conclude such matters are wrong. A proposal may be no novelty; it is only a novelty to them.

Moreover, years ago there was so much bitter controversy on the silver question that the moment a writer approaches it, even remotely, prejudice is aroused with many not fully informed and whose minds are not in possession of information on changed conditions.

Nevertheless, in view of apparently inevitable action by European countries in the not distant future, a brief resumé from an American standpoint on the subject of silver as affecting United States production and export of the metal and American trade and commerce with silver-using countries is opportune at this time.

The 1915 report of the director of the U. S. Mint contains much germane information furnishing food for thought.

UNITED STATES LEADING SILVER PRODUCER

While the United States has long been one of the leading producers of silver, the price of the metal has been practically fixed in London.

The 1915 mint report furnishes the following information:

The production of gold and silver from the mines of the United States, from 1792 to 1914 inclusive, is stated as:

TABLE I

	1913	1914
North America:		
United States	\$40,348,100	\$40,067,700
Canada	19,041,000	15,097,300
Mexico	42,705,100	89,089,200
	\$102,094,200	\$94,264,200
Central America	1,290,000	1,336,500
South America	7,328,600	7,155,000
Europe	9,215,500	8,448,400
Australasia	10,949,800	1,946,700
Asia	3,130,400	2,998,400
Africa	637,900	570,000
Total	\$135,246,400	\$116,719,200

Gold, 175,859,429 fine ounces; value, \$3,635,331,200.
Silver, 2,158,431,200 fine ounces; *commercial* value, \$1,749,585,300.

The sources and *commercial* value of the world's production of silver for 1913 and 1914 are given as follows, at \$0.604 per ounce for 1913 and at \$0.553 per ounce for 1914:

It is obvious that North America is especially interested in the future of silver.

MINTS CLOSED AGAINST COINAGE OF SILVER "ON PRIVATE ACCOUNT"

Space does not admit of details of the adoption of the single gold standard by various countries.

In 1873 the U. S. Congress passed an act whereby subsidiary U. S. silver coins and a "trade dollar" of 420 grains weight (in lieu of the previous standard silver dollar) coined at the expense of the depositor, i.e., "on private account," should thereafter be a legal tender at their nominal value for any amount not exceeding \$5 in any one payment.

In 1876 Congress took from the "trade dollar" its legal-tender quality and authorized the Secretary of the Treasury to limit its coinage to its demand for exportation. The coinage of this dollar (intended for use in trade with China and Japan) practically ceased in 1878, and its further issue was prohibited in 1887.

In 1878 Congress passed the Bland-Allison act, which directed the Secretary of the Treasury to purchase, at best rates possible, silver bullion to the amount of not more than \$4,000,000 worth nor less than \$2,000,000 worth per month, to have it coined into silver dollars of full legal-tender power and to issue certificates, receivable for any Government dues, upon the deposit of those coins in the Treasury. This act brought into circulation two new elements—silver dollars (the coinage of which had been prohibited since 1873) and the silver certificates.

In 1890 Congress passed an act providing for the purchase of 4,500,000 ounces of silver bullion each month and the issue in payment therefor of Treasury notes, and repealing so much of the act of 1878 as required the monthly purchase and coinage of silver bullion.

In 1893 Congress repealed the clause in the act of 1890 directing the purchase of silver bullion and the issue of Treasury notes therefor.

In 1893, also, the mints of India, with its 259,000,000 of silver-using people, were closed to the "free coinage" (i.e., on private account) of silver rupees. In other words, private parties were no longer permitted to take their silver bullion or personal ornaments to the mints of India and (subject to a small charge for the cost of coining) receive the equivalent in silver rupees.

CLOSED MINTS AUTOMATICALLY DEPRECIATE SILVER

The 1915 U. S. mint report reveals the following information:

Since 1873 the commercial ratio of silver to gold has more than doubled.

The commercial ratio of silver to gold for 186 years, i.e., from 1687 to and including 1872, was practically steady, the minimum for any one year (1760) being 14.14 and the maximum (1812) being 16.11.

From 1873 the ratio rose from 16.16 in that year to a maximum of 39.74 (1909), in 1914 being 37.49.

Since 1873 the gold value of an ounce of silver has declined more than 50 per cent.

The value per ounce of silver (1000 fine) in U. S. gold coin, based on the average price of bar silver in London, for the eighty-two years, from 1833 to 1914

inclusive, was practically steady, rising from \$1.297 in 1833 to a maximum of \$1.360 in 1859, and in 1873 was \$1.29769.

From 1873 it declined to a minimum of \$0.52016 in 1909, in 1914 being \$0.55312.

Since 1873 the bullion value of the silver dollar has declined more than 50 per cent.

The bullion value of the silver dollar (371¼ grains of pure silver) at the annual average price of silver each year from 1837, commenced in 1837 at \$1.009, attained its maximum of \$1.052 in 1859, and declined from \$1.00368 in 1873 to a minimum of \$0.40231 in 1909, in 1914 being \$0.42810.

WHAT BECOMES OF SILVER MINED IN UNITED STATES

The 1915 mint report furnishes interesting information of the use of U. S. silver in coinage, arts and manufactures and exports.

For the 122 years from 1793 to 1914 inclusive, the U. S. Government coined silver of the *coinage* value of \$506,234,355, the amount for 1913 and 1914 being stated as: 1913, \$3,184,229; 1914, \$6,083,823. No standard silver dollars have been coined since 1904.

The difference between the *commercial* value and the *coinage* value of the silver coined is called "seigniorage," and is the profit of the Government.

The stock of silver coin in the United States on June 30, 1915, is estimated at \$753,701,905, and the stock of silver bullion in U. S. mints and assay offices on June 30, 1915, at \$4,337,516.

For the thirty-five years from 1880 to 1914 inclusive, the amount of silver (U. S. coin, domestic and foreign bullion and foreign coin) furnished for use in manufactures and the arts amounted to 485,500,570 fine ounces.

The exports of silver bullion (presumably *commercial* value, though not so stated) from the United States from 1900 to 1914 inclusive are as follows:

United Kingdom	\$640,557,856
Asia	98,235,551
All Other Countries.....	61,702,956
	\$800,496,363

A great part of the silver exported from the United States to the United Kingdom is re-exported from London to the Orient, and the report gives the details of the enormous silver export, from 1881 to 1914 inclusive, from London to India, China and the Straits Settlements.

SILVER COINAGE BY FOREIGN COUNTRIES

The silver coinage of the world for 1913 and 1914 alone, when the average market price of silver per ounce was \$0.60458 for 1913 and \$0.55312 for 1914 (the *coinage* value calculated in U. S. money), was:

1913	\$131,125,727
1914	120,932,328

The ten leading countries (outside the United States) being as follows:

	1913	1914
Austria-Hungary	\$10,929,392	
China	15,829,272	\$19,419,143
France	4,179,250	
Germany	12,168,426	16,010,633
Great Britain	8,241,662	
India	55,551,112	17,608,768
Japan	2,138,127	
Netherlands	321,600	7,268,362
Persia	2,872,495	4,756,890
Russia	3,442,293	

For the fifteen years 1900-1914, during which the United States exported, as shown above, silver bullion to the amount of \$800,496,363, the market price of silver averaged less than 58 cents per ounce.

Foreign countries have made, in the aggregate, enor-

mous profits out of the "seigniorage" of coining cheap silver originating in the United States.

INDIA NOW GOLD "SINK HOLE"

The great majority of the 295,000,000 of people of India do not use banks as Americans do, from the wealthiest down to the poorest more or less hoarding their surplus coin, many people of small means having same made into bracelets, anklets, etc., for their wives, who thus become the family "safety deposits." Others hide their coin reserves, while the wealthier have secret strong rooms or receptacles for bullion and coin.

For fifty years prior to the closing in 1893 of the Indian mints to the coinage of rupees "on private account" the import of silver into India was four times that of gold, and India was known as the "sink hole" of silver, as that metal once gone into India practically never came out.

The change of standard in India in 1893 from silver to gold resulted in India's precious metal imports, from 1896 to 1910 inclusive, being in the proportion of 100 of gold against 64 of silver.

In 1910 the Indian Government imposed a 16 per cent duty on all silver bullion imported into India, resulting in increasing imports of gold (mostly for hoarding purposes) and declining imports of silver.

The annual statistics for the fiscal years 1873 to 1912 inclusive show the enormous excess of imports of gold and silver into India over the exports from India, the excess gold imports increasing at a rapid rate in recent years, from 1896 to 1914 inclusive, amounting to more than 27,000,000 ounces of gold of the value of more than \$540,000,000!

This abnormal Indian absorption and hoarding of gold has practically offset the benefit to the world's trade and commerce of the increased gold output of South Africa and elsewhere in recent years, and has materially intensified the gold shortage in Europe.

CHEAP SILVER ESPECIALLY BENEFITS THE ORIENT

Cheap silver especially benefits the great silver-using countries of China, India, Japan, etc., in their international trade with (and at the expense of) the gold-standard countries in Europe and the United States.

Kaiser William of Germany once referred to the Oriental nations as the "Yellow Peril." Cheap silver is developing them into a commercial and manufacturing "Yellow Peril" to the gold-standard countries of Europe and the United States.

Years ago it was predicted that, with the decline in the market price of silver, "the yellow man with the white dollar would beat the white man with the yellow dollar" in international trade and commerce. That prediction is being verified.

Cheap silver, involving fall in exchange between gold-standard countries and silver-using countries, is an increasing tariff in favor of the Asiatic producer and manufacturer, as against imports from gold-standard countries, but, unlike a tariff, Asiatic exports are not reduced, but are, so to speak, subsidized.

While India and Japan are nominally on a gold-standard basis, silver is the money metal of the great masses of the people. China is wholly on a silver basis.

Since the commencement in 1873 of the fall in the market price of silver, the rise in the rate of wages and cost of living in the great silver-using countries of the Orient has been inconsiderable.

The standard silver coins of those countries and their equivalent values in U. S. gold coin are: China, the "tael," about 55 cents; India, the "rupee," about 32 cents; Japan, the "yen," about 49 cents. Those coins have almost as great a purchasing power in the internal

trade and commerce of their respective countries today as they had years ago.

But in international trade between those countries and the gold-standard countries of Europe and the United States, cheap silver stimulates Asiatic factories and exports and fosters the competition of yellow labor with white in important trades—iron, coal, steel, textiles, etc.

The greater the amount of silver that Asiatic countries have had to pay for the purchase, on a gold basis, of imports from the gold-standard countries, the more the Asiatic countries were driven, in self defense, to manufacture for themselves wherever possible and cease importing to that extent.

Silver, as a mere commodity, without recognition at the mints of the world at any internationally fixed ratio with gold, naturally fluctuates in market price, and to that extent renders more difficult trade and commerce between the gold-standard countries of Europe and the United States and the populous silver-using countries of the Orient.

For instance, as the bullion price of silver falls, it becomes more difficult to continue exports to China. No merchant in China can buy exchange (in other words, buy gold) on London, Paris or New York, so that cheap silver assists Chinese mills and other manufacturing industries, protecting them from competition of imported foreign goods, which would be possible with higher-priced silver, and especially with an international-fixed ratio between silver and gold.

Cheap silver stimulates Asiatic exports to the markets of America and Europe for the simple reason that the Asiatic exporter who formerly sold his products for one British sovereign or for five U. S. gold dollars received in exchange for that sovereign or five gold dollars three "taels" only. With cheaper silver, he now receives for that British gold sovereign or five American gold dollars, not three, but eight "taels." The same general conditions prevail in India and Japan, and the great industrial development since 1873 in the silver-using countries is very largely owing to cheap silver.

With the opening of the Panama Canal and Japan's development of her mercantile marine in the Pacific, the gold-standard countries are confronted now, more than ever before, with the industrial menace of cheap silver—of "the yellow man with the white dollar."

All of which demonstrates that this country is vitally interested in any action found necessary by the European countries looking to the increased use of silver as a money metal, at some internationally fixed ratio of silver with gold, thereby permanently enhancing and steadying the future market price of silver to the great advantage of Europe and the United States, with corresponding impetus to international trade and commerce.

The consent and co-operation of the United States will be necessary to perfect any such action by the European countries.

THOMAS TONGE.

Denver, Col.

[In publishing Mr. Tonge's article we do not wish to commit this journal in any way on the political aspects of the question, but feel that the interesting and timely statistical information contained in Mr. Tonge's article merits the attention of silver producers and metallurgists in general.—Editor METALLURGICAL AND CHEMICAL ENGINEERING.]

Arizona Copper Strike Ended

The four months' labor strike at the Shannon Copper Company's, the Detroit Copper Company's, and the Arizona Copper Company's works in the Clifton and Morenci district in Arizona has been ended on Jan. 24.

The wages are increased. The union is not recognized. Any future differences are to be settled by conferences between company officials and employee committees.

There is to be an immediate resumption of mining, milling and smelting. The normal production is 6,000,000 lb. of copper monthly.

Mineral and Chemical Exploration Act Passed

The House of Representatives has passed an act "to authorize exploration for and disposition of coal, phosphate, oil, gas, potassium and sodium," reported favorably by the House Committee on Public Lands.

The measure has now gone to the Senate, where it has been referred to the Committee on Public Lands of that body.

Important features of the measure as it passed the House are as follows:

The Secretary of the Interior is authorized to lease to any qualified applicant any deposits of phosphates or phosphate rock belonging to the United States, through advertisement, competitive bidding or such other methods as the secretary may by general regulations adopt. Each lease shall be for not to exceed 2560 acres of land, the land to be in compact form, the length of which shall not exceed two and one-half times its width. For the privilege of mining, royalties, to be fixed by the secretary in advance of offering the land, are to be paid, not less than 2 per centum of the gross value of the output, and an annual rental, which shall not be less than 25 cents per acre for the first year, 50 cents for the second, third, fourth and fifth years, and \$1 per acre thereafter, the rental to be credited against the royalties. Leases are to be for indeterminate periods upon condition of a minimum annual production. There is a strike clause, and there is to be a readjustment every twenty years. Lessees are to have not more than forty acres of the surface of unentered lands for prospecting.

The Secretary of the Interior is authorized to grant prospecting permits for chlorides, sulphates, carbonates, borates or nitrates of potassium or sodium, or associated similar salts, for a period of not exceeding two years. Areas are likewise limited in this case to 2560 acres. Upon discovery of valuable deposits, permits are to be entitled to patents for 640 acres. Leases are to be permitted upon terms similar to those outlined in the case of phosphates or phosphate rock. In addition to the 640 acres, 20 acres are to be allowed for camp sites, refining works, etc.

The provisions of the act apply to deposits "owned by the United States, including those in national forests, the Grand Canyon National Monument, and the Mount Olympus National Monument," but excludes those in national parks, "and in lands withdrawn or reserved for military or naval purposes."

The provisions of the act as to coal specifically excludes deposits in Alaska. Common carriers are not allowed to take coal deposits larger than needed for their own purposes, and are limited to one lease for each 200 miles of line. A royalty and lease-fee system, such as is specified for phosphates and phosphate rock is provided for coal.

In the case of oil and gas, prospecting permits are provided for, upon lands "located within ten miles of any producing oil or gas well." In the territory of Alaska prospecting permits may be granted for periods not exceeding four years. Patents for leases may be granted for one-fourth of the land embraced in the prospecting permit. Timber is reserved to the United

States. Leases shall be for a period of twenty years, subject to renewal, the payment to be not less than \$1 per acre per annum. Rights-of-way through public lands for pipe lines are provided for.

The rights conferred by the act are upon "citizens of the United States, or to any association of such persons, or to any corporation organized under the laws of the United States, or of any State or territory thereof, and in the case of coal, oil, or gas, to municipalities." No corporation shall hold any interest as a stockholder of another corporation in more than one lease, No lessee shall hold more than a tenth interest in any agency engaged in the sale or resale of coal, phosphate, oil, gas, potassium or sodium, obtained from such lessee. Moneys derived are to be paid into and appropriated as a part of the Reclamation Fund.

Hearings on Proposed Dyestuff Tariff

Hearings were held on Jan. 14 to 15, before the House of Representatives Committee on Ways and Means, for the purpose of obtaining information on the dyestuff situation in order that legislation may be passed if possible to encourage the industry in the United States. The subject of the hearing was the so-called Hill bill (H. R. 702), which would place a duty on all dyes and intermediates. Technical experts, manufacturers of dyestuffs, and representatives of dyestuff consumers were present and testified at the hearing.

About the same time as the opening of the hearings, the Bureau of Foreign and Domestic Commerce issued a report by Thomas H. Norton (Special Agent Series No. 111). In this report Dr. Norton gives the status of the dyestuff situation as in November, 1915. He states that before the war 3300 tons of dyes were made here, while now about 15,000 tons are made. A list of the industries dependent on dyestuffs is given, together with a list of the present manufacturers of intermediate and finished dyes. Dr. Norton states that the Department of State has exerted every effort for eight months to secure the free passage of German dyestuffs to our ports. No results have thus far been obtained. The Department of Commerce has also exerted every effort to alleviate the situation and is strongly in favor of protecting and fostering the American industry. The manufacture of coal tar crudes, Dr. Norton says, has assumed large proportions, but, owing to the great demand for such products in the manufacture of explosives, the dyeworks cannot get adequate supplies.

At the hearings before the Committee on Ways and Means, which is the tariff-making body of the House, the general consensus of opinion was strongly in favor of the bill. As to its effect, the general opinion seemed to be that it would not give much immediate relief except in unloading whatever supplies might be hoarded, but its future effect would be to encourage present manufacturers to increase their output and to induce new capital to enter. Some were in favor of a dumping clause, in addition to the bill to prevent unfair competition after the war. The possibility of using the dye factories for explosives was also strongly brought out, and future chemical independence and the foundation of an American organic chemical industry were other strong points presented in favor of the bill.

The first expert called by Chairman CLAUDE KITCHEN was Dr. BERNHARD C. HESSE, representing the chemical and dyestuff committee of the New York Section of the American Chemical Society. Dr. Hesse first read a letter of the committee to Hon. E. J. Hill under date of Jan. 7, 1916. (The original report of this committee, which furnished the basis for the Hill bill, was published in our issue of December, 1914, Vol. XII, page 753.)

LETTER FROM CHEMICALS AND DYESTUFFS COMMITTEE

NEW YORK, January 7, 1916.

HON. E. J. HILL,

House Office Building, Washington, D. C.

SIR: H. R. 702 is, in part, based upon the report of the chemicals and dyestuffs committee to the New York section of the American Chemical Society appearing in the Congressional Record for December 10, 1914, copy of which is hereto attached.

The undersigned, constituting the complete membership of seven of that committee, herewith submit, at your request, their justification of—

(1) The rates proposed in that report and by you incorporated into H. R. 702, and

(2) Their expectation that as a result of such duties a complete, self-contained, and independent coal-tar chemical and dye industry will eventually result in the United States.

The professional activities of these seven men and the industrial occupations represented by them on this committee are as follows:

- (1) Manufacture of heavy chemicals.
- (2) American coal-tar dye producers.
- (3) Textile interests.
- (4) Importers of coal-tar dyes.
- (5) American producers of crude coal-tar products.
- (6) Leather and tanning interests.
- (7) Chemical expert in coal-tar dyes.

In 1882 this country possessed a coal-tar dye industry that promised to grow into something worth while. There was then a duty of 35 per cent ad valorem and 50 cents per pound specific. When this specific duty was removed in 1883, whatever we then had of a coal-tar dye industry languished and has since been practically without effect. A specific duty has since then not been levied.

In 1908 two of the largest American coal-tar dye plants then in existence (Schoellkopf, Hartford & Hanna Co., of Buffalo, and Heller & Merz Co., of Newark, N. J.) submitted to the Committee on Ways and Means under date of November 9, 1908, at the hearing of November 11, 1908 (pp. 128-130, vol. 1 of the official record of those hearings), a detailed statement as to the added protection they would require in order to compete successfully in this market against European-made dyes, but themselves using European-made intermediates. In that elaborate cost statement they showed that a proposed materials cost of 13.22 cents per pound for finished dyes as against an existing cost of 14.76 cents (i. e., a materials cost decrease of 1.54 cents per pound), together with an increase in the ad valorem rate from 30 per cent to 40 per cent, would enable them to successfully compete, although using foreign-made intermediates. At the same time and place they also showed that the corresponding materials cost for the same finished dyes per pound in Germany was 10.57 cents.

Reverting now to the tariff in effect in 1882, this committee is dependably informed that the then average import value of the great bulk—that is, from two thirds to three-fourths of all the European-made coal-tar dyes entering this country—was a little over \$1 per pound, and this notwithstanding the statement of from 50 cents to 60 cents made by Mr. John Campbell under date of July 26, 1882, at pages 154-156, volume 1, of the Report of the Tariff Commission of 1882. If this committee's information of the \$1 figure be correct, then the specific duty then in effect was essentially one-half of the fair average import value of the bulk of the dyes reaching this country from Europe.

This committee was further dependably informed that in 1914, before the outbreak of hostilities, the fair average import value of the bulk—that is, from two-thirds to three-fourths of all the dyes reaching this country from Europe—is 15 cents. If, therefore, the specific duty of 7½ cents be now added to the prevailing ad valorem of 30 per cent, the tariff conditions of 1882, under which we did have something in the way of coal-tar dye industry, would be substantially reproduced, and under those conditions it is not unreasonable to expect that the industry would again flourish in this country.

In all of the tariff legislation heretofore enacted some of the coal-tar dyes were put upon the free list; also the intermediates have been more or less (principally more) upon the free list. In other words, the protection afforded to the coal-tar dye industry has never been such as to cover the entire industry, but only segregated parts thereof. Each and all of these tariff enactments failed to provide for a co-ordinated protection of the making of intermediates and of the production of the finished dyes therefrom all in this country.

Therefore, this committee recommended that this isolated and "spotty" protection be removed and all dyestuffs, by

whatever name known and produced in whole or in part from materials obtained or obtainable from coal tar, should be treated alike for tariff purposes; all should be taxed 30 per cent ad valorem plus 7½ cents per pound specific.

In general, the German 1913 export price of intermediates is about one-half that of finished dyes. Therefore, this committee compensated the specific on finished dyes to the intermediates by adding a specific duty of 3.75 cents per pound on all intermediates. This committee suggested a 15 per cent ad valorem duty on intermediates as against 30 per cent ad valorem on finished dyes because, compared with the finished dyes, with the intermediates being made in larger units and larger amounts, the handling costs in manufacturing intermediates in the factory are less than the handling costs for finished dyes.

Returning now to the statement of Messrs. Schoellkopf and of Messrs. Heller & Merz above referred to, the added protection due to the three proposed increased ad valorem would amount to 1.5 cents on dyes of an average value of 15 cents entering this country. Adding this 1.5 cents to the 1.54 cents above shown gives, as a total, an added 3.04 cents protection per pound on dyes of the above-stated fair average import value.

As a test case of the net effect of this schedule of rates upon the production of the cheapest dyes, this committee further had the benefit of the following calculations based upon the assumptions now to be given:

The dye known as Orange II is probably the type of the cheapest of the dyes that are imported into this country. It is made by assembling two intermediates known, respectively, as sulfanilic acid and betanaphthol. In general, 173 pounds of sulfanilic acid and 144 pounds of betanaphthol will yield 350 pounds of the commercial dye in its highest commercial concentration. There were four cases assumed with regard to respective import values, as follows:

Case	Orange II	Sulfanilic Acid	Betanaphthol
	Cents	Cents	Cents
I	8	4	6
II	8	8	8
III	12	6	9
IV	12	4	6

The calculated respective added advantages for 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, and 10 cents specific for the dyes, and half of each for intermediates with an ad valorem of 30 per cent and 15 per cent, respectively, in cents per pound of Orange II, due to this schedule of rates, would therefore be as follows:

Case	6 Cents	6.5 Cents	7 Cents	7.5 Cents	8 Cents	8.5 Cents	9 Cents	9.5 Cents	10 Cents
	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents
I	2.61	2.88	3.16	3.43	3.70	3.98	4.25	4.52	4.80
II	2.34	2.61	2.89	3.16	3.43	3.71	3.98	4.25	4.53
III	2.13	2.40	2.68	2.95	3.22	3.50	3.77	4.04	4.32
IV	2.02	2.29	3.17	3.44	3.71	3.99	4.26	4.53	4.81

From this tabulation it is clear that 7.5 cents is the lowest specific rate that gives a practically 3 cents added protection per pound of this cheap dye under this variety of price circumstances and combinations.

It is therefore clear that the rates that this committee suggested meet the following three conditions:

(1) Recreate the tariff conditions of 1882 to conform as nearly as possible to the altered conditions of 1914.

(2) Give the industry that makes dyes from intermediates the added assistance that in 1908 it showed to be necessary for its continuance in business.

(3) Protect the domestic intermediates maker.

There is also the added advantage to the dye-making industry that all of the coal-tar dyes are dutiable and none are free and that all intermediates are dutiable and none are free.

That the committee's assumption that 15 cents represents the fair average import value of the bulk of the dyes reaching this country in 1914 is reasonably near the truth is shown further by the average materials and labor costs given in the statement of Messrs. Schoellkopf, Hartford & Hanna Co., and of Messrs. Heller & Merz of 1908 just referred to. The combined labor and materials costs in Germany of the 3,000,000 pounds of dyes there referred to is 12.62 cents per pound. Our present consumption of dyes is between 50,000,000 and 60,000,000 pounds per year.

In order to visualize the effect of these proposed rates

upon intermediates and dyestuffs and the total protection afforded, the following table is submitted:

PROTECTION AFFORDED UNDER PROPOSED RATES							
Cents per Pound	Specific	Ad Valorem	Total Protection	Cents per Pound	Specific	Ad Valorem	Total Protection
INTERMEDIATE DYES				FINISHED DYES—			
	Cents	Cents	Per ct.		Cents	Cents	Per ct.
4.....	3.75	0.60	4.35	109	cont'd		
5.....	3.75	0.75	4.50	90	7.5	3.0	10.5
6.....	3.75	0.90	4.65	76	11	3.3	10.3
7.....	3.75	1.05	4.80	69	12	3.6	11.1
8.....	3.75	1.20	4.95	62	13	3.9	11.4
9.....	3.75	1.35	5.10	57	14	4.2	11.7
10.....	3.75	1.50	5.25	53	15	4.5	12.0
11.....	3.75	1.65	5.40	49	16	4.8	12.3
12.....	3.75	1.80	5.55	46	17	5.1	12.6
13.....	3.75	1.95	5.70	44	18	5.4	12.9
14.....	3.75	2.10	5.85	42	19	5.7	13.2
15.....	3.75	2.25	6.00	40	20	6.0	13.5
16.....	3.75	2.40	6.15	38	21	6.3	13.8
17.....	3.75	2.55	6.30	37	22	6.6	14.1
18.....	3.75	2.70	6.45	36	23	6.9	14.4
19.....	3.75	2.85	6.60	35	24	7.2	14.7
20.....	3.75	3.00	6.75	34	25	7.5	15.0
25.....	3.75	3.75	7.50	30	50	15.0	22.5
FINISHED DYES							
8.....	7.5	2.4	9.9	124	75	22.5	45
9.....	7.5	2.7	10.2	113	100	30.0	37.5
					150	45.0	52.5

In 1913 the average export value out of Germany of intermediates was 10.07 cents per pound and of finished dyes 21.53 cents per pound. Therefore, these proposed rates give a total protection of 53 per cent to this average value of intermediates and of 65 per cent to this average value of finished dyes, and, furthermore, conform very closely to the tariff conditions in 1882 and satisfy the 1908 requirements of the United States dye makers mentioned; and, in addition, protect the entire class of coal-tar dyes and their respective intermediates and give the prospective American intermediate maker a protection which he has hitherto never enjoyed.

This committee further believes that with this protection on the cheaper dyes the domestic manufacture of the more expensive varieties of dyes, of pharmaceuticals, of medicines, and of explosives will follow almost as a matter of course.

In order that there may be given as little opportunity as possible for evasion of the duties contemplated to be imposed by the report of this committee, this committee now respectfully suggests to you that H. R. 702 further contain a definition of what is to be a coal-tar dye for the purposes of this act, so that such things which under our present adjudications are not coal-tar dyes and are not coal-tar dye intermediates will be obliged to pay the duty of coal-tar dyes.

The materials we have in mind are the dye bases known as magenta base, Victoria blue base, Victoria green base, Bismarck brown base, auramine base, crystal violet base, methyl violet base, rhodamine base, chrysoidine base, and the like, which are imported in that condition and merely require the addition of a small amount of muriatic acid thereto to convert them into the commercial forms of dyes. In the form of bases, they are neither dyes nor intermediates and they pay 20 per cent as coal-tar preparations; they are not dealt in on the European markets; they have no fixed market value; the importation value into the United States can be whatever the exporter chooses. In this connection it will be necessary to look into the language employed by the court in the decision reported under Treasury decision 34,400 in volume 26 for January to June, 1914, and 5 Customs Court of Appeals. Furthermore, the language used in the cases cited in Treasury decision 28,003 with regard to bromofluorescent acid should be consulted so as to prevent evasion along the line of those products which are dye acids and need merely the addition of a small amount of soda ash to convert them into commercial dye forms. It would not do to place these rates upon coal-tar dyes and then enable foreigners to ship into this country things that are not dyes and not intermediates under our present adjudications and which merely need the addition of a negligible amount of muriatic or other acid or of soda ash or of similar material to convert them into the real dyes of our adjudications. It is obvious that if any such loophole were permitted to stand the result expected of those rates would not take place—i. e., a complete, self-contained and independent coal-tar, chemical, and dye industry within the borders of the United States.

This committee further suggests that in placing natural indigo on the free list, the wording selected be such as possibly to exclude indigo not derived from vegetable sources from that free list.

From the point of view that the protective duty contemplated to be added by these proposed rates will reappear in whole or in part in the form of a direct addition to the normal cost of dyestuffs, it is clear that those users of dyestuffs that have in whole or in part hitherto enjoyed the free list will bear the greater relative proportion of such putative increase. Whether such addition will actually take place or not this committee expresses no opinion; it merely states the maximum that can reasonably be expected in the way of increased cost to the users of dyes in this country. In other words, as we stated in our above report, namely: It will, therefore, be necessary to determine carefully if the advantages to be gained are equal to the price to be paid.

The committee herewith unanimously reaffirms its belief that the rates proposed in its report of November, 1914, above referred to, are the lowest at which a self-contained, complete, and independent coal-tar, chemical, and dye industry can be created in this country, and which at the same time offer a legitimate incentive to legitimate capital for a legitimate effort to produce these goods in this country. Whether capital will avail itself of this advantage or not this committee expresses no opinion.

As to this schedule of rates proposed—

(1) It is the probable lowest schedule that will induce complete, self-contained, and independent manufacture within the United States.

(2) It meets and very closely duplicates the tariff conditions existing in 1882 when we did have something of an industry of this kind.

(3) It meets the requirements set forth in 1908 as necessary to maintain a dye industry in this country, which dye industry then operated with foreign-made intermediates.

(4) It provides at the same time a suitable protection to the making of intermediates within the United States.

(5) It puts all dyes of coal-tar origin upon one and the same level for tariff purposes and also puts all such intermediates upon one and the same level for tariff purposes.

(6) It gives a protection of 53 per cent on the average value of all intermediates and of 65 per cent on the average value of all finished dyes, such average values being average export values out of Germany for 1913.

Respectfully submitted.

BERNHARD C. HESSE, *Chairman*, J. B. F. HERRESHOFF, I. F. STONE, J. MERRITT MATTHEWS, H. A. METZ, D. W. JAYNE, ALLEN ROGERS.

Dr. Hesse said in the hearings on Jan. 14 that the rates proposed reproduce as near as possible the relative conditions existing in 1882, when this country did have something of an industry. They reproduce also, as nearly as possible, the added protection asked for in 1908, and a complete protection for manufacture of intermediates has been added. Furthermore, it is proposed to remove from the free list all products of this kind; in other words, protection is put on everything. In that way, by giving added protection to the manufacturer of intermediates in this country, and at the same time giving the manufacturer of dyestuffs, who employs these intermediates, the protection that he asked for in 1908, and reproducing at the same time the conditions of 1882, when this country did have something of an industry, are the reasons why it is expected—and believed that the expectation is justified—that if those conditions are reproduced in 1915 or thereabouts that this country will then have something of an industry.

Dr. Hesse said there were plenty of coal-tar crudes available before the war. He said it had been understood that Schoellkopf, Hartford, and Hanna of Buffalo had not been very successful since 1882. He said that when intermediates come in free this country only has an assembling industry, and when these are shut off the industry is choked. In regard to natural indigo being placed on the free list, Dr. Hesse said 95 per cent of the indigo used was synthetic, so this made little difference. He did not think the German industry was protected to any great extent by patents, as 99 out of 100 patents are "misfires."

Dr. Hesse said the dye users should co-operate with the manufacturers by telling them what they want and in what amounts. He said the difference in the cost of labor was one factor in determining a tariff.

Another factor discussed was the relation between explosives and dye manufactures. Dr. Hesse said: "We are rapidly approaching a position where we are independent of any foreign country except Chile for any materials that we may want for defense." If we had a complete coal-tar dye industry we would have an equipment and workmen which could quickly be shifted to making explosives. However, the two industries are not inextricably joined, as one could easily exist without the other. At present Dr. Hesse said our production of coal-tar products was going mostly for explosives. The output is greater than we would need for dyes. He said substantial relief could not be expected in from six months to three years.

A statement was read to the committee from the Monsanto Chemical Works, St. Louis, Mo., in which they stated that they had previously imported raw materials for their products, which are fine and medicinal chemicals. They have expended \$200,000 on new equipment to manufacture their own raw materials and want protection. They state that they will be supplying their products at reasonable prices in from thirty to sixty days.

Dr. J. MERRITT MATTHEWS, consulting engineer, of New York City, was next called. Dr. Matthews is a member of the committee of the American Chemical Society, of which Dr. Hesse is chairman, and said that he had come into pretty intimate contact with quite a number of textile organizations, and they have all evinced a strong desire to see a dyestuff industry established in this country, looking toward it as a method of insurance that present conditions shall not recur. He always understood production costs in Europe were far less than ours, but he could not state exact comparative costs. It is not a question of increasing costs to the textile men; it is a question of saying whether they shall continue in business. One per cent is a high average limit for cost of dye in the finished product. The addition in the price of goods is high now on account of abnormal price of dyes, but in normal times the increased cost with the proposed tariff on would be very small. One cent would cover the increase on a suit of overalls.

To make finished dyes requires an organization, and there is considerable inertia to overcome. People are loth to go into it unless they have assurance of protection. The bill would not prohibit imports, as there would be a demand for many dyestuffs not developed in this country. We should receive a practical benefit in twelve months, and some dyes could be made in three months. Others would take years.

Ability to make explosives is also an important point, and should be the first consideration. Great Britain has subsidized her industry with Government participation, under the name of British Dyes, Ltd. They have passed prohibitive laws dealing with Germany. Russia has done the same. Of course, resentment may have played a part in their action.

Dyes should be lower in price after a time through competition. It is not likely at present that the textile industries would ask for an increased tariff on textiles if a dyestuff tariff would be enacted. The levying of the tax would not produce the results it would have produced in 1908, when so many mills opposed the increase tariff on dyes. It is absolutely essential that intermediates be given protection to have a complete industry, and since the value of the intermediates is, roughly speaking, one-half the value of the dyestuffs, the committee concluded that the intermediates should bear one-half the ad valorem duty and one-half the specific duty of the finished dyestuffs.

Mr. L. A. AULT of Ault & Wiborg Co., Cincinnati,

Ohio, manufacturers of printing inks, said they were now making their own intermediates and some dyes for their own use, otherwise their factory would have been closed during the past four months on many essential colors. He was strongly in favor of the bill, and cited as an example the tin plate industry, which was fostered by the McKinley bill, while tin plate is now selling at much lower price than when the law was enacted, and this country is an exporter in the bargain. All colored printing stops when the dyes are shut off. Newspaper inks are, however, not affected.

Mr. HERMAN A. METZ, importer, manufacturer and consumer of dyes and also a member of Dr. Hesse's committee, said in part: The increased cost of dyes if made here would not affect consumers. Labor is not such an important item. The plant with which he is connected in Germany is running with two-thirds of its force. The 30 per cent duty covers the difference in labor costs. His company, the Consolidated Color & Chemical Co. of Newark, has expanded to three times its former size, and he is now making his own intermediates. The rates proposed are the minimum which are necessary. Benzol and acids at present are hard to obtain, due to munition manufacture. The bill will not help during the war as raw material cannot be obtained fast enough. This country will not make all colors, as the very fine colors will still be imported.

Mr. HERBERT H. DOW of the Dow Chemical Co., Midland, Mich., said that his company went ahead and took the chance, and is now erecting a plant with a capacity of 1000 lb. of dry indigo per day. He expects to have it finished in July. He is not confident of competing with the Germans until the tricks of the trade are learned. He thinks the tariff could be removed after the industry is established if dumping is prevented.

Prof. CHARLES H. HERTY, president of the American Chemical Society, said in part that he does not consider this question that is before us now as the usual tariff problem, but the mills of this country are suffering and a crisis is here. The organic industries are lacking greatly in this country in the way of chemical industries. It is impossible to develop all lines at once, so that the by-products of one industry could be used in another, as Germany has succeeded in doing in fifty years of experience. Apparatus is hard to get in view of the present shortage of steel, and methods given in the literature are often purposely deceiving.

Five or six years ought to be enough to get the majority of the manufacturers in good shape. As a Democrat he wrestled with this question a long time, and is now convinced that if this country is to have an industry it must have a protective tariff. He thinks one thing which has been shown up through the European war, and which is clear now to all, is the value of chemistry to a nation. His hope and desire to see the dyestuff industry proper is because it is going to stimulate all kinds of chemical work; it is going to put chemistry on a higher plane in this nation. It is to the interest of the cotton-goods men who look forward to export trade to have American-made dyes rather than get them from competitors in the cotton-goods business. There are a great many things brewing in this country ready to get started, and everyone is looking to Congress. There need not be unfair prices as a result of this tariff as German competition and the Sherman anti-trust law ought to prevent that.

Mr. J. F. SCHOELLKOPF, president of Schoellkopf Aniline & Chemical Works, Buffalo, N. Y., said in part: The rates proposed may be sufficient as the manufacturer of intermediates may be able to sell his products without being obliged to take full advantage of the proposed duty, but if a rapid expansion is desired the

rates should be increased. In addition to an adequate tariff on all coal-tar products and colors, some effective anti-dumping legislation will have to be enacted. Without such a clause, nothing can prevent the crushing of the domestic industry if the foreign conventions so decrees. Another question to be considered is whether or not the Government should assume some sort of supervision.

His company is making nearly all its own intermediates and the labor cost is about 40 per cent. They could make explosives in a week and go back to colors in a week. Only the intermediate plants are used in making explosives. They have increased their capacity 125 per cent since the war. He does not think anything like 15,000 tons of colors are now being produced. About 5000 tons is nearer the right amount. They have had experiences with unfair competition in the way of underselling. Dyes have been sold here for 18 cents, paying 30 per cent duty, when they were selling in Germany for 22 cents. His company expects to be making 7000 tons per year within the next two months, and could soon double that output if machinery could be obtained. The plant is already built for increasing to 7000 tons per year. They did it because they were enabled to make products from their raw materials and products for which their intermediates could be used. They tried to make enough to pay for the plant and make a profit besides. With increased production they ought to be in a better position to compete.

Mr. Schoellkopf submitted tables which he had previously submitted in 1908 and 1913, showing the cost of a complete plant and production costs for an output of 3,000,000 lb. of dyes per year. The production cost was figured as 1.34 times the cost in Germany under the proposed tariff and 1.44 times under the present tariff.

Dr. WM. BECKERS, president of W. Beckers Aniline & Chemical Works (Inc.), Brooklyn, N. Y., said that this country may even lose the 15 per cent of business it had before the war if the tariff is not revised. Alizarin dyes which come in free, constitute one-third of the money value of the entire importation. It is not fair to leave them untaxed. They are mostly the finer colors used on expensive material bought by well-to-do people who can better stand the increased cost than those using goods made with cheaper dyes. American consumers have not enjoyed the benefit of the duty-free colors as the foreign conventions have placed their prices as they wished. Revision must be done in a thorough and correct way so that alongside of the other already highly developed industries of the United States a "modern organic chemical industry" can be substantially and intelligently built up as a whole on American soil. The German Government will assist the dye-makers in preventing any foreign industry to develop. The rates proposed could be increased, but they may be sufficient. They surely will not create a hot-house industry. If the bill is passed he will have four or five millions at his disposal instead of one-quarter of a million.

Mr. EDWARD MOIR, president of the Carded Woolen Association, said that the increased cost on a suit of clothes would only be two-thirds of a cent.

Mr. H. B. THOMPSON of the United States Finishing Co., New York City, said the dyeing cost in cotton goods is only 0.15 to 0.18 cent and the increase would be infinitesimal. An advance of 5 cents in the price of indigo would raise the cost of dyeing cotton goods $\frac{1}{4}$ cent on a 3-yard drill and 1-10 cent on 7-yard 64-square calico. Eighty per cent of the New England trade favor the bill. As to entering into contracts with dye-makers for dyestuffs to help foster the industry, that is not practical on account of the changing styles.

Much more testimony was given of the present shortage in clothing, the effect of the shortage of dyes reaching way back to the cotton planter and sheep raiser, and various figures of cost were given as to increases which would result in the cost of goods. For the most part the opinion was that the increased cost would be slight, and in most cases would be absorbed before it got to the consumer. Some were skeptical as to whether any immediate relief would result, but all favored the bill as beneficial for the future. Among those giving further testimony were the following: Mr. Ludwig Stein, chairman of dyestuffs committee of National Association of Clothiers; Mr. George W. Wilkie of R. H. Comey & Co., New York; Mr. J. K. Milliken, representing the National Association of Cotton Finishers; Mr. Frederick E. Kip, president Saltson Textile Manufacturing Co.; Mr. W. D. Livermore, chief chemist American Woolen Co.; Mr. John Alden of Pacific Mills; Mr. Chas. L. Auger, president National Silk Buying Co., Paterson, N. J.; Mr. Horace B. Cheney of Cheney Bros.; Mr. John W. Snowden, representing the Upholsterers of Philadelphia; Mr. D. F. Waters, president Master Dyers' Association; Mr. Jos. E. Ralph, director Bureau of Engraving and Printing. Many letters were presented by Congressmen from the various manufacturing districts favoring the bill. The hearings adjourned at 8 p. m. on Jan. 15.

Congress Likely to Create a Tariff Commission

President Wilson is understood to have reached a decision to ask Congress to create a tariff commission, and it is said in Washington that it is more than likely that he will outline his views on the subject at the coming convention of the Chamber of Commerce of the United States, when he will speak before that body, the night of Feb. 10.

Such a proposal is likely to receive the approval of Congress, it is said in Washington, as many members of both political parties are in favor of such a commission. A place was made on the Ways and Means Committee of the House, the tariff body of the House, for Representative Longworth, when he returned to Congress, and almost his first act was to introduce a bill providing for such a commission. It is understood he was encouraged to do so by Democratic members, Mr. Longworth being a Republican.

President Wilson until recently believed, it is understood, that the Federal Trade Commission has the powers of a Tariff Commission, but he is now said to have come to the conclusion that the powers of that body are entirely too limited to meet the demands of the business world for a real tariff commission. The President will propose, it is said, a broad-gaged commission, with full power to treat the tariff in a scientific manner, and he may recommend that the commission be bi-partisan. The President, in common with other economists, it is said in Washington, has given consideration to the situation which will follow the European war, and has been urged to take measures which will prevent the "dumping" of foreign goods on the United States market when the war ends.

The bill of Representative Longworth, which may become the basis for debate and action, provides for a commission of five members appointed by the President, and holding terms of two, three, four, five and six years respectively, the term of each to be designated by the President but their successors are to be appointed for six years each. Under this bill the President would designate the chairman. Any member could, after a

hearing, be removed by the President for inefficiency, neglect or malfeasance. Not more than three members could be of the same political party. Votes would be by quorum. The chairman would receive \$7,500 a year and the other members \$7,000 a year. Rather large powers, under the bill, are granted for secretarial and other help, the latter assistance being mentioned in this way: "Such other employees as it may find necessary to the performance of its duties." The office of the commission would be in Washington, but it would have authority as a body or by one or more of its members "to conduct investigations at any other place or places, either in the United States or foreign countries." Expenses are allowed both for the commission and its employees and witnesses. The duties of the commission are thus defined under this bill:

"To investigate the cost of production of all articles which by any act of Congress now in force or hereafter enacted are made the subject of tariff legislation, with special reference to the prices paid domestic and foreign labor and the prices paid for raw materials, whether domestic or imported, entering into manufactured articles, producers' prices and retail prices of commodities, whether domestic or imported, the condition of domestic and foreign markets affecting the American products, including detailed information with respect thereto, together with all other facts which may be necessary or convenient in fixing import duties or in aiding the President and other officers of the government in the administration of the custom laws and such commission shall also make investigation of any subject whenever directed by either House of Congress."

The commission would make reports either to the President or Congress as they might direct. Power to require the production of books and papers of manufacturers, etc., is given. The bill prohibits the making public of information which would be of value to business competitors.

Electrochemical Industries as Affected by the War

Program of New York Section Meeting of the American Electrochemical Society

The program of the meeting of the New York Section of the American Electrochemical Society, to be held at the Chemists' Club on Feb. 11, is particularly interesting and timely, as the subject will be "The Electrochemical Industries as Affected by the War." This will be a joint meeting with the New York sections of the American Chemical Society and the Society of Chemical Industry. The speakers will be:

Lawrence Addicks, on electrochemical war supplies.
W. S. Landis, on air saltpeter.
E. D. Ardery, on hydrogen for military purposes.
Albert H. Hooker, on new war products.
William M. Grosvenor, on metallic magnesium.
G. Ornstein, on liquid chlorine.
George W. Sargent, on electric steel.

The date for the annual spring meeting of the American Electrochemical Society is April 27, 28, 29, and the place is Washington, D. C.

Program of 112th Meeting of American Institute of Mining Engineers

Arrangements for the annual meeting of the American Institute of Mining Engineers to be held in New York City from Feb. 14 to 17 have been completed, and everything points to a very interesting and enjoyable meeting. Headquarters will be at the Engineering Societies Building, 29 West Thirty-ninth Street, New York City.

Monday night, Feb. 14, will be college night, Tuesday night the smoker, Wednesday night the annual banquet at the Hotel Astor, followed by dancing, and Thursday will be devoted to an all-day excursion.

The technical program contains papers of great interest in the various sections. The meetings of the different sections are as follows:

Monday, Feb. 14: 10 a. m., session on petroleum and gas; 2 p. m., session on coal and coke; 2 p. m., session on geology.

Tuesday, Feb. 15: 10 a. m., business meeting and technical session; 2 p. m., technical session.

Wednesday, Feb. 16: 10 a. m., session on iron and steel; 10 a. m., session on precious and base metals; 2 p. m., session on iron and steel.

Resolution of the American Institute of Mining Engineers on the Chihuahua Murder

The following resolution was passed at the meeting of the Board of Directors of the American Institute of Mining Engineers on Jan. 21, 1916:

Resolved, That this Board has learned with indignation and sorrow of the unprovoked and brutal murder of eighteen American citizens on Jan. 10, in the State of Chihuahua, Mexico, and laments especially the death of Messrs. C. R. Watson, C. A. Pringle, H. C. Hase and W. J. Wallace, who were members of the American Institute of Mining Engineers. As these men and their companions were engaged in the lawful prosecution of their work, we trust that nothing will be allowed to prevent or delay appropriate action by our Government concerning the outrage by which they lost their lives.

Resolved, That the sincere sympathy of this Board and of all the members of the Institute is extended to the families and friends of Messrs. C. R. Watson, C. A. Pringle, H. C. Hase and W. J. Wallace.

And be it further resolved, that a copy of this resolution be sent to the Secretary of State of the United States, be published in the Institute's Bulletin, in the press, and be sent to the families of the deceased members.

Annual Meeting of the American Paper and Pulp Association

The American Paper and Pulp Association will meet in annual convention at the Waldorf-Astoria Hotel on Wednesday and Thursday, Feb. 16 and 17, 1916.

The entire day on Thursday will be given over to the Technical Section, a special meeting being held in the forenoon and a general meeting in the afternoon. Committee reports will be presented at the forenoon session, the following subjects receiving consideration: Soda pulp and recovery processes, Martin L. Griffin, chairman; Sulphate pulp and kraft paper, Otto Kress, chairman; Mechanical pulp and improvements in grinding, D. L. Bellinger, chairman; Sulphite pulp and processes, Robert B. Wolf, chairman; Reports on methods of testing materials used in the manufacture of paper, H. P. Carruth, chairman.

At the afternoon session the typical apparatus used in the manufacture of pulp and paper will be exhibited and their operation demonstrated. Special forms of barkers for pulpwood will be shown in this way and new methods of drying paper will be shown. It is intended to open the afternoon session to all interested in the pulp and paper industry irrespective of membership, and a large attendance is expected.

Headquarters for the Technical Section will be established at the Waldorf-Astoria Hotel, in charge of Thomas J. Keenan, secretary. The officers of the Technical Section of the American Paper and Pulp Association and the standing committees are:

Executive Committee—Henry E. Fletcher, chairman, Fletcher Paper Company, Alpena, Mich.; W. G. MacNaughton, Nekeosa-Edwards Paper Company, Port Edwards, Wis.; Ernst Mahler, Kimberly-Clark Company, Neenah, Wis.; Charles F. Rhodes, Bureau of Tests, International Paper Company, Glens Falls, N. Y.; Henry F. Obermanns, Hammermill Paper Company, Erie, Pa.

Publication Committee—Charles F. Rhodes, Bureau of Tests, International Paper Company, Glens Falls, N. Y.; Henry F. Obermanns, Erie, Pa.; Thomas J. Keenan, New York.

Soda Pulp Committee—Martin L. Griffin, chairman, Oxford Paper Company, Rumford, Me.; Sidney D. Wells, Madison, Wis.; Edwin Sutermeister, Westbrook, Me.

Sulphate Pulp Committee—Otto Kress, chairman, Forest Products Laboratory, Madison, Wis.; Joseph E. Hedin, Wilmington, Del.; George S. Holmes, Orange, Texas.

Sulphite Pulp Committee—Robert B. Wolf, chairman, Burgess Sulphite Fibre Company, Berlin, N. H.; F. C. Clarke, Washington, D. C.; C. C. Heritage, Port Edwards, Wis.

Standard Methods of Testing Materials Used in the Manufacture of Paper Committee—H. P. Carruth, chairman, American Writing Paper Company, Holyoke, Mass.; Raymond C. Hatch, Holyoke, Mass.; Max Cline, Glens Falls, N. Y.

Groundwood Committee—D. L. Bellinger, chairman, Finch, Pruyn & Company, Glens Falls, N. Y. Associates not yet named.

The Western Metallurgical Field

The Extension of Flotation

Of all the work that has been done with the flotation process, we have heard the least about its application to ores of metallic copper. Such ores, of course, are limited in distribution, being practically confined to the northern peninsula of Michigan. Nevertheless the recovery of finely divided metal is quite as much of a problem there as the slime problem is anywhere, and it is reasonable to presume that flotation should offer some advantages over present methods. This subject has been under investigation by the metallurgical department of the Michigan College of Mines, testing ore from two new properties. Flotation is found to give a much better extraction than ordinary gravity methods, but up to the present the concentrates produced are not sufficiently high grade to be handled in the type of smelting equipment usually found in Michigan. If flotation is to be applied with any degree of success, means must be found for producing a better grade of concentrate, or smelting methods must be revised. Both these suggestions are feasible, but in all probability the most advisable thing to do would be to improve the concentrates to meet the smelting conditions, since the latter are peculiarly adapted to the product of Michigan copper mills.

Progress with flotation is being made in the Cripple Creek district, where several companies have been making investigations for some months past. The Portland has definitely decided on the Callow pneumatic process, and is operating some machines in the old Stratton's Independence mill, which it purchased some time ago. It is likely that the Portland people will put this mill on a custom basis and handle ores from different parts of the district, as the plant is favorably situated for such work. Another concern that has been making extensive tests is the Vindicator, and there is a possibility that a large mill may be built for the treatment of low and medium-grade mine and dump ore.

The successful application of flotation to Cripple Creek ores appears to have been no simple matter, and several failures have been reported by individuals called upon to make tests. Those who have pursued their experiments further, however, have apparently succeeded where others failed. One essential to success seems to be the use of an unusually large quantity of oil, up to 6 lb. per ton. Such a quantity would entail considerable expense were it not for the fact that very cheap oils seem to be adapted to this work. It is in-

teresting to speculate on the future of flotation in Cripple Creek, and its effect on cyanidation. Flotation plus smelting may prove more economical than cyanidation of low-grade ores; or the cyanidation of flotation concentrates may be developed to a point where, by reason of the cheapness of flotation and the comparatively small quantity of high-grade concentrate to be cyanided, a much larger tonnage of ore may be treated in the district. Of course, it is impossible to say at this time what the developments may be, but there is a possibility that they may affect the status of present practice in the district, as well as the former strategic position of the mills treating high-grade ore at Colorado City.

Unusual conditions are being encountered in applying flotation to different ores. In the case of a certain zinc ore it was impossible to apply the process satisfactorily until copper sulphate was added to the water. In another instance, tests on a zinc ore gave satisfactory results at the testing laboratory in the city, but when the process was tried at the mill in the mountains the results were negative. Examination of the mountain water proved it to be almost free from salts; and suspecting that this might be the source of trouble, the metallurgist added mineral salts of various kinds to the water and accomplished that the results of test work were duplicated at the mill. Incidents like these give food for thought in regard to the theories of flotation, and lend weight to the arguments in favor of an electrical theory.

Tests on a Washington Complex Low-Grade Silver Ore

The department of mining engineering of the State College of Washington, under the direction of Prof. F. A. Thomson, has been conducting a research on the metallurgy of certain complex low-grade silver ores of Okanogan, Wash.¹ Some of the ores in this district consist mainly of pyrite, sphalerite, galena and tetrahedrite in a gangue of bluish-white quartz. The analysis of one of the ores is as follows:

	Per Cent
Copper	1.55
Lead	3.70
Zinc	4.3
Iron	6.25
Antimony	3.3
Lime	1.05
Sulphur	6.80
Silica	72.01
Alumina	0.7
Silver, oz. per ton	26.0

Assays of the segregated minerals of the ore show the gold to be contained in the galena and tetrahedrite. Silver is more widely distributed, but is mainly concentrated in the tetrahedrite. The results are shown below:

Mineral	Gold, Oz. per Ton	Silver, Oz. per Ton
Quartz	None	None
Pyrite	0.02	26.4
Sphalerite	None	29.5
Galena	0.16	71.1
Tetrahedrite (gray copper)	0.12	347.6

This ore was tested both by leaching and concentration; cyanidation and hyposulphite treatment being given under the first method, and gravity concentration and flotation under the second.

Cyanidation.—Treatment of the raw ore proved impracticable, yielding only 50 per cent extraction, with excessive cyanide consumption. Little or no improvement was gained by preliminary treatment with caustic alkali and metallic aluminium, as practiced at Cobalt. Chloridizing roasting followed by cyanidation gave an extraction of 65 per cent, the loss being 15 per cent in roasting and 20 per cent in the tailing. Sulphatizing roasting followed by water wash to remove soluble cop-

¹Bulletin 101.

per proved entirely unsuitable as a preliminary treatment. The best result was obtained by a light, thirty-minute chloridizing roast, water wash and cyanidation. This gave a total extraction of 88 per cent, the loss being 7 per cent in roasting and 5 per cent in cyaniding. The extraction of copper by the water wash was above 80 per cent.

Hyposulphite Treatment.—Oxychloridizing roast followed by water wash and leaching with sodium hyposulphite gave a silver extraction of about 70 per cent. Copper extraction by water wash was about 80 per cent.

Concentration Tests.—Treatment of each screen size in glass sorting column yielded an extraction of 70 per cent; ratio 10:1. Cyanidation of the tailing recovered an additional 18 per cent, making a total recovery of 88 per cent by the combined treatment. Straight concentration on a Wilfley table, with ore crushed to 40-mesh, gave a recovery of 80 per cent; ratio 4:1. A combination treatment was given by tabling the —40 + 100 grade and floating the —100. The tabling gave a recovery of 80 per cent with a ratio of $4\frac{1}{2}$:1; and flotation with eucalyptus oil in acid solution gave an extraction of 73 per cent at a ratio of $3\frac{1}{2}$:1. Treatment by flotation exclusively gave the highest recovery, 91 per cent of the silver and 95 per cent of the copper. The ore was crushed to pass 80-mesh and was floated with a mixture of eucalyptus oil and wood creosote in non-acid solution. The concentration ratio was $2\frac{1}{2}$:1.

The tentative choice seems to lie between (a) light chloridizing roasting followed by water wash and cyanidation, and (b) flotation of the entire ore crushed to pass 80-mesh. The latter process, of course, yields a product which may have to be shipped to smelters, but experiments are under way to determine the feasibility of cyaniding this product after a light chloridizing roast followed by water wash.

Producing Tungstic Acid at Boulder, Col.

Until quite recently the only local treatment of Boulder County tungsten ores consisted in concentration, the enriched products being shipped East for metallurgical treatment. At different times various concerns have investigated the advisability of further local treatment, producing a finished product suitable for use in metallurgy, chemistry or the textile industry, but nothing came of these investigations. Within the past month, however, the Tungsten Products Co. has been incorporated by J. H. Holmes, H. B. Holmes and Warren F. Bleecker, for the manufacture of tungsten products at Boulder, Colo. Mr. Bleecker is metallurgist in charge of technical work.

The immediate purpose of the company is the production of tungstic acid. Later on metallic tungsten may be produced. The raw material is low-grade tungsten ore mined in the Nederland district immediately west of Boulder. Low-grade ore is being used in preference to high-grade concentrate on account of the much lower cost per unit of tungstic acid contained. In brief the process consists in roasting the ore with soda ash, leaching the sodium tungstate with hot water and precipitating tungstic acid with hydrochloric acid. The ore and soda ash in proper proportions are ground in a pebble mill. The mill is lined with maple wood and the grinders are flint pebbles of local origin. The ground mixture is roasted on a reverberatory hearth, observing important precautions to secure a high percentage of soluble sodium tungstate, as well as certain physical conditions in the product which will make the subsequent leaching efficient. The roasted mixture is then transferred to vats where it is leached with water heated by live steam. The solution is filtered by vacuum, and tungstic acid is precipitated

by the addition of hydrochloric acid. This precipitate is separated from the liquor by decantation and filtration, and forms a product of immediate commercial value. While the elements of the process are comparatively simple, the success of the work depends on maintaining certain conditions in each step. The work at Boulder is starting on a small scale, with plans for enlarging as conditions demand.

Sulphuric Acid in Utah

An index of the development of chemical and metallurgical industry in Utah is found in the announcement by C. W. Whitley, general manager for the Utah department of the American Smelting & Refining Company, that his concern will shortly erect in the Salt Lake valley a sulphuric acid plant. It is reported that the manufacture of acid will be in conjunction with the smelting operations of the company, utilizing the sulphurous smelter gases. If the company's experiments in zinc hydrometallurgy with electrolytic deposition prove successful enough to warrant the construction of a commercial plant, much of the sulphuric acid produced will be used in the treatment of zinc ores.

Anaconda's Electrolytic Zinc Plant

The success of Anaconda's experiments in the production of electrolytic zinc is definitely settled by the announcement that a \$2,000,000 plant is to be constructed at Great Falls where cheap electric power is available. Research on this subject has been under way for months, and will now culminate in a plant that is to be in operation about September of this year. The reported capacity is 70,000,000 lb. per annum, and the power requirement 30,000 hp. Zinc concentrate will be roasted and leached with sulphuric acid. The solution will then be purified by precipitating iron by means of limestone and copper and cadmium by zinc. The purified zinc sulphate solution will then be electrolyzed with insoluble lead anodes and either aluminium or zinc cathodes.

Potash Production in Utah

The Mineral Products Company, which is exploiting the alunite deposits near Marysvale, Utah, now has its plant in operation and is producing about 25 to 30 tons of potassium sulphate per day. This pioneer work, started under the favorable conditions created by the war, is meeting with success, and the company is now contemplating the production of aluminium as well as potash. A carload of alumina by-product from potash manufacture has been shipped East for experimental tests, with the expectation of ultimately building a reduction plant in Utah. The concern is backed by men prominent in the packing and mining industries.

Record Production in the Joplin District

Joplin is rejoicing in a production of lead and zinc in 1915 valued at over \$26,000,000. This is a record that has no equal in former years, the nearest approach being in 1912, when the value was over \$18,000,000. Zinc concentrates constituted the largest portion of the tonnage and commanded the highest price per ton of any product of the district. In June the base price for 60 per cent zinc concentrates reached the record price of \$135 per ton. The new year opened with prices of \$85 to \$115 per ton for 60 per cent zinc and \$70 for galena, and the prospect for continued prosperity is as bright as could be asked. There appears to be no cessation in the construction of new mills and treatment plants following in the wake of high prices, and new settlements have even sprung up around plants constructed by some of the larger companies.

The Utilization of Wood Waste

A paper read at the Baltimore meeting of the American Institute of Chemical Engineers, on Jan. 12, 1916.

BY ARTHUR D. LITTLE

Mark Twain says, "We all talk about the weather, but nothing is done." So it is with wood waste utilization. The lumbermen are interested, of course, but their interest is tempered by weariness and restrained by scepticism. They are open to conviction but would like to see anyone who can convince them. Much the same situation may be found where any of our great industrial wastes are concerned. Those who are responsible for the wastes are so close to them and so long familiar with them that they have come to regard them as the unavoidable accompaniment of the industry. Moreover plans for waste utilization commonly involve the extension of a business into regions which, however familiar they may be to those doing business in them, are new and strange to the makers of the waste. Conversely, those whose specialized experience might enable them to utilize the waste to advantage, hesitate to incur the large capital expenditure required for establishing an industry dependent upon a raw material over which they have no control and the supply of which may cease at any time, as, for example, when a lumber mill burns down.

These are real and serious obstacles in the way of the utilization of wastes, but the things which any one can do easily bring no great rewards. The world belongs to those who overcome difficulties and nowhere does it offer richer promise of potential wealth made actual than in the colossal wastes of lumbering.

The figures involved are of astronomical proportions and consequently make little more impression on the mind than the distances of the fixed stars. Let us, however, try once more to really comprehend them. On a total annual cut of 50,000,000,000 ft. broad measure, of merchantable lumber, at least 75,000,000,000 ft., or about 112,000,000 tons of wood waste is produced. For every man, woman and child in the country there is therefore annually wasted more than a ton of wood.

The proportion of waste to merchantable lumber varies within wide limits with the kind of wood. In the lumbering of hard woods, according to Goodman, only 15 per cent of the weight of the standing timber appears as finished lumber. Sixty-five to 70 per cent of the original tree is left on the ground and the mill waste amounts to over a cord per 1000 ft. of lumber. Frankforter, who had exceptional opportunities for studying the lumber industry in the middle, northern and western States reports that in these sections of the country the best equipped and most skillfully operated mills utilize a little less than 40 per cent of the total weight of wood in lumber, lath and shingles. Our own large scale studies on long-leaf yellow pine have proved that under the best operating conditions only 33.42 per cent of the average tree becomes available as lumber, box shooks, lath and shingles. Two-thirds is wasted. In the estimate given above of total annual waste an average of 60 per cent of the entire tree was reckoned as waste, but in view of the loss on yellow pine, which is our most important timber tree, and the far greater proportionate loss on hardwoods, it is evident that the total annual waste is substantially more than 75,000,000,000 ft. and may even reach 90,000,000,000 ft. Frankforter's estimate of 100,000,000,000 ft. on a smaller annual cut is undoubtedly too high and not in accordance with his other figures.

Of all our timber trees none lends itself more readily to waste utilization than long-leaf yellow pine. It is cut more largely than any other species and the individual operations are commonly on a great scale

which ensures the local concentration of waste in vast amounts. For these reasons and because my associates and I have studied the waste utilization problems presented by this wood more carefully than those of any other species I will ignore hardwood distillation, the use of extracted chestnut chips for pulp and paper making and the occasional use of mill waste from northern conifers in sulphite pulp mills, and ask you to direct your attention solely to the utilization of wood waste from long-leaf yellow pine.

The present annual cut of this species is about 15,000,000,000 ft., board measure. The waste is equivalent to 30,000,000,000 ft. It may be said at once without fear of successful contradiction that the potential profits in this waste are far greater than any actual profits which this branch of the lumber industry can be made to yield from lumber. When this waste is intelligently considered, not as waste, but as raw material, it will be seen to afford a basis for building up the greatest group of co-related by-product industries the world has ever seen. The products of these industries will comprise wood pulp, pulp boards, paper, paper bags, paper twine, turpentine, rosin, pine oil, charcoal, tar, ethyl alcohol, cattle feed, varnishes, ether, and not improbably acetic acid, wood alcohol, acetone and producer gas.

The wood of long-leaf pine is heavy, exceedingly hard, very strong, tough, coarse-grained, compact, durable and very resinous. Its density varies with the height from the ground, the age of the tree and its content of pitch or oleoresin. Sargent gives the average specific gravity as about 0.7, which would seem to be too high. Determinations in the Forest Products Laboratory ranged from 0.426 to 0.583. Determinations in our own laboratory gave 0.626 as the specific gravity of round wood averaging 7 in. in diameter. The weight per cubic foot for logging waste we found to be 39.1 lb. bone dry. The weight per cord depends greatly upon the shape and size of the pieces. On the dry basis we have found the sawdust to weigh about 1400 lb., mill waste with little or no bark 2340 lb., with much bark 1708 lb., logging waste in the form of fairly smooth round logs weighs about 3260 lb., and if rough and irregular will average 1860 lb., while mature long-leaf pine, consisting largely of heart wood, will run about 4300 lb. to the cord, bone dry.

We find the ultimate composition of long-leaf pine to be: Carbon, 53.96 per cent; hydrogen, 7.13 per cent; oxygen, 38.65 per cent; nitrogen, 0.03 per cent; sulphur, 0.04 per cent; ash, 0.16 per cent.

Our determinations of fuel value of average sawmill dust gave 9240 B.t.u., dry basis. Moisture in green wood averages 34.15 per cent, fresh green stumps average 28.69 per cent, lightweight 13.35 per cent. Stumps about six years old carry around 20 per cent of water and kiln-dried lumber contains an average of about 10 per cent.

The proportion of bark varies to some extent with the age of the tree and is relatively high. Small round Mississippi wood had about 9 per cent, Florida pulp wood over 11 per cent, and Florida trees, 18 in. diameter, bore 8.6 per cent of bark by weight.

Determinations in our laboratory of the fiber length of long-leaf pine gave a maximum of 7.40 mm., minimum 3.00 mm., with an average of 4.60 mm., as compared with 3 to 3.5 mm. for spruce.

In determining the amount of field waste under careful operation members of our organization selected five plots of one acre each as truly representative as possible of the average quality of yellow pine timber. As soon as the timber had been felled the waste between 3 in. and 9 in. was collected, classified and weighed. Much of it was also corded and scaled to determine relations

between weight, cord measure and volume. Each stump was measured and its volume and weight computed. Needles from four trees were weighed.

The main points of accumulation of mill waste are the main refuse conveyor and the main dust conveyor. Actual determinations by weight of the amounts of waste carried by these conveyors in very large scale operations were made by members of our staff. The results of these determinations in the field and at the mill enable us to state with a very close approximation to the truth the relative proportions of the initial products of the average yellow pine tree. They have perhaps never been ascertained before within such limits of accuracy or upon so large a scale. The proportions of the several products are as follows:

Tops and culls.....	22.35
Logs.....	70.56
Stumps and lightwood.....	7.09
	100.00

Bearing in mind that all percentages given are on the total weight of the tree, the tops and culls consist of:

	Per Cent
Needles and twigs.....	2.35
Limbs under 3 in.....	2.54
Cordwood.....	6.42
Pulpwood.....	4.54
Red and rotten.....	6.60

The logs yield:

	Per Cent
Red and rotten.....	1.45
Slabs, edgings and trimmings.....	18.07
Sawdust and shavings.....	17.62
Shingles.....	0.06
Lath.....	1.39
Lumber and box shooks.....	31.97
Stumps amount to.....	6.54
And lightwood to.....	0.61
	100.00

Comprehensive studies were conducted on these wastes for a period of eight months. The different classes of waste were carefully and repeatedly analyzed and their content of rosin and turpentine determined. Papers in great variety were made in our experimental paper mill under direction of Mr. V. E. Nunez, and extractions and distillations on the small commercial scale carried out in our Forest Products Department by Dr. L. F. Hawley. The results obtained, together with data from actual commercial practice, point incontestably to these stupendous totals:

Upon an annual cut of 15,000,000 ft. of yellow pine the lumber industry in our Southern states now wastes raw material sufficient for the concurrent daily production of 40,000 tons of paper, 3000 tons of rosin, 300,000 gal. of turpentine and 600,000 gal. of ethyl alcohol, together with fuel sufficient to meet the requirements of all these industries.

Despite the prevailing opinion to the contrary among lumbermen, and even among papermakers, long-leaf yellow pine lends itself admirably to the manufacture of paper. It is too pitchy for the sulphite process, but is readily reduced to pulp by the soda process. Much the best results are, however, obtained by the sulphate process which when carried out under proper conditions yields an excellent kraft pulp and paper. The pulp bleaches with some difficulty, but may with care be brought to good color without serious impairment of strength. The bleached pulp makes good wood writings and when mixed with pulp from gumwood can be run off into good book papers. A cord and a half of round waste makes a ton of paper as against about two cords of spruce costing Northern mills from \$9 to \$13 a cord.

The production of ethyl alcohol from yellow pine waste by the Ewen & Tomlinson process has been fully demonstrated as a technical proposition, about 90,000 gal. of high-grade 95 per cent alcohol having been made

in the plant of the Standard Alcohol Company at Fullerton, La. The commercial merit of the proposition remains to be demonstrated since this company is now in the hands of the receiver for reasons altogether apart from the technical merit of the process. It may, however, be said that every technical man familiar with the process believes that it is capable of producing 95 per cent alcohol at a cost, including cooperage and all fixed and manufacturing charges, of not more than 20 cents a gallon. Such alcohol is worth to-day about 56 cents a gallon. The yield per cord of sawdust or hogged wood waste containing 50 per cent water is 10 gal. in large-scale operation, but yields much higher have been obtained in the laboratory.

The process is based, of course, on the observation of Braconnot in 1819 that cellulose by treatment with mineral acid is converted into reducing and fermentable sugars. For nearly 100 years experimenters have endeavored to develop this observation into a commercial process. With the exception of Ewen & Tomlinson all have failed to produce alcohol in commercial quantities. Simonsen in Sweden, in 1889, began a series of brilliant researches which cleared up many points of difficulty and ultimately enabled him to secure very satisfactory results on the large laboratory scale. Attempts at commercial operation, however, developed fresh obstacles, and led to the abandonment of the process. The well-known German chemist, Alexander Classen, patented during the years 1900, 1902 and 1903 various modifications of the general process of producing sugars and alcohol by treatment of comminuted wood with strong acids under heat. Subsequently several plants were built in this country for carrying out one or another of these modifications. In none of them were any substantial amounts of alcohol produced and the Classen process must be regarded as commercially inoperative. It remained for Ewen & Tomlinson to overcome the fundamental technical difficulties underlying all these attempts and to put forward the first process capable of large-scale production of ethyl alcohol from wood.

The Ewen & Tomlinson process is essentially one for producing fermentable sugars. The fermentation of these sugars, once produced, may be carried out and the alcohol recovered in any distillery by the usual methods. It is my belief that the process affords the cheapest known method for producing these sugars, and that it therefore is ultimately destined to become an important if not the most important source of industrial alcohol.

In carrying out the process hogged wood waste usually containing about 50 per cent of water is loaded into a rotary digester holding about seven cords and having a protective and heat insulating lining. Sulphuric acid in relatively small amount is sprayed upon the wood and then steam is admitted to the digester. The critical temperature is reached as quickly as possible, and the reaction is then extremely rapid, if not indeed nearly instantaneous. Pains are therefore taken to immediately reduce the pressure and to empty the digester of its contents as promptly as may be. About 25 per cent of the weight of the wood is converted to reducing sugars, not all of which are fermentable.

The cooked material, which is not unlike coarse coffee grounds in appearance, is transferred by conveyors to a diffusion battery or other extraction apparatus in which the sugars are dissolved out. The spent chips go to a continuous press for removal of excess water and are then available as fuel. The extracted juice is neutralized with lime, and is then ready for fermentation. The concentrated slop from the stills finds use as cattle feed, and is about equivalent to molasses for that purpose.

In a modification patented by me the process may be

diverted as a whole to the production of carbohydrate cattle feed. In this modification hydrochloric acid is substituted for sulphuric and subsequently removed so far as readily possible by heating or blowing air through the mass. The remaining acid is then converted to common salt by addition of an equivalent amount of sodium carbonate. The juice is extracted and concentrated to the consistency of molasses.

A major economic problem in the South which is bound up with the utilization of wood waste is that of the agricultural development of the cut-over lands. It has been demonstrated that by a steam puller yellow pine stumps may be pulled for about 33 cents each. In the trials made the stumps averaged 563 lb. each, which makes the cost of pulling \$1.16 per ton. Where logging train roads are still in place the stumps can be brought to a central plant for treatment at a total cost well within \$2.50 per cord. Treated by solvent extraction they should yield per cord about 6 gal. of turpentine, 2½ gal. of pine oil and 380 lb. of resin. The extracted chips as pointed out by Veitch and Merrill, and amply demonstrated in our experimental paper mill, are available for the manufacture of an excellent grade of kraft paper. Strangely enough and contrary to our first impression the charred portions common in such stumps are easily removed in the process and leave the paper clean. The chips are, of course, also available for alcohol production.

Stumps and the highly resinous wood residues termed lightwood, together with the box slabs from turpentinized trees, are directly available for treatment by several processes of distillation. The average green wood, with 35 per cent moisture, contains about 6 per cent resin, but in selected samples of wood the resin may run higher than 50 per cent. No large quantities are usually to be had, however, containing more than 30 per cent. The composition of the resin itself is variable, but in green wood it runs about 80 per cent resin, and 20 per cent volatile oils; about 80 per cent of the latter are turpentine and the balance pine oil.

Destructive distillation is carried on in retorts operated commonly without temperature control. Average yields under these conditions are:

Light oils	6 gallons
Turpentine	6 "
Heavy oil	16 "
Tar	48 "
Charcoal	35 bushels

Various processes in which the retort temperature is controlled, as in the bath process and the processes of Gautier, Pritchard, and others, have been proposed, and several put in operation for a time on either the commercial or large experimental scale. They offer advantages in the way of better yields and quality of turpentine, but these gains are so nearly offset by higher fuel costs and higher maintenance charges that the commercial superiority of these more complicated processes has yet to be demonstrated.

Ten years ago recovery of turpentine from comminuted waste by steam distillation was practiced in many plants, the steam being blown through the mass of chips either upward or downward, and carrying with it to the condenser the volatile oils. The decline in the price of turpentine in 1907 and 1908 proved so severe a blow to the industry that it is to-day practically wiped out.

The well-known Yaryan process added to the steam distillation method the subsequent step of extracting the chips with a volatile solvent from which the dissolved resin could later be recovered. Several plants of large capacity were operated successfully until in 1913 the failure of the American Naval Stores Co. caused a heavy drop in the price of resin, which was

followed by the failure of the company operating the Yaryan process. A contributory cause may well have been the large losses of solvent incident to the process.

Several methods have been proposed for the recovery of turpentine, pine oil and resin from yellow pine wastes by the action of water solutions of alkali, but none are thought to be operating commercially. They depend upon the fact that the wood is only slightly attacked by the dilute alkali in which the resin is readily soluble. Nevertheless, some wood is dissolved, and the difficulty of separating this so-called "humus" from the resin has prevented the introduction of processes of this type. The difficulty has been overcome in a simple and ingenious way by Whitaker and Bates, who salt out the resin soap by increasing, after the initial treatment of the wood, the concentration of the alkaline solution to 3½ per cent free alkali. The treated chips are then available as a raw material for paper making.

When the real work of wood waste utilization has once begun and the attention of chemical engineers and financial men has been drawn more generally to the huge potential values now ignorantly thrown away we may expect the rapid development of these byproduct industries and the initiation of many new ones to the great enrichment of the South and in somewhat less degree that of the Northwest. It would doubtless be too sanguine to expect the directive impulse for this new development to come from the lumbermen themselves. They are too close to the wastes. They are blinded by the sawdust. But if they fail much longer to grasp the opportunity which has been so long beside them they must be content to see others reap the benefits and profits which will come through control of processes, special apparatus, and, above all, of technique.

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Oils and Other Reagents in Flotation

BY ROBERT J. ANDERSON

The advent and application of the flotation process, as it is now understood by its more authoritative exponents, marks one of the most noteworthy and revolutionary advances in modern metallurgical endeavor. Flotation marks a new era in the concentration of ores and of intermediary mill products. Although the process was discovered some fifty-five years ago, it is only recently that mill men and others have come to a realization of its virtues and have applied its principles on a commercial scale. This tardy application of a process so long known must necessarily be ascribed to certain inherent difficulties, which were encountered and which could only be effaced by time. Since it is not so long ago that the process was uncertain of success, the rapid strides made in the last few years can be regarded as nothing short of remarkable. Recently flotation has demanded the attention of mine operators, mill men, and others interested in the mining and metallurgical welfare of the country, particularly the United States Bureau of Mines and the bureaus of experimental research in connection with the universities teaching mining and allied subjects.

Disregarding here the mention of the manifold number of patents which have been taken out for the flotation process, the subject of litigation, and the theories which have been advanced to explain the "why" of flotation, it may be safely stated that probably nothing relative to the application of flotation on a commercial scale has received the attention which the oils have. It is a well-known fact that virtually any kind of oil, grease, or oleic acid may be used in this process; the number of oils or rather combinations of oils which have

been tried experimentally and commercially is almost without end.

This use of oils has given impetus to the production of wood creosotes and other wood fractions particularly in the South, the market for which had hitherto become rather stagnant; further, the increased production of coal tars and similar distillates in coke and gas manufacture has lately been more warranted; then, too, the petroleum industry has had a share in furnishing oils for flotation consumption.

To-day there are probably 200 flotation plants in active operation in this country, and this number is rapidly increasing as time proceeds. The flotation process will undoubtedly have a far-reaching application, but in no sense can it be looked upon as a universal panacea for all metallurgical ills. There can be little doubt that the process has come to stay, and probably its full significance is not even now realized. The metallurgical treatment of the concentrates produced in flotation presents an entirely new problem not hitherto encountered in metallurgical work and also a field for active research.

Oils in Flotation

There are so many oils available for use in flotation work that judicious selection has become a factor almost as important as the quality of an individual kind. In spite of the fact that considerable experimental work has been performed pertinent to the use and application of oils in flotation, there is a decided dearth of data regarding their effects and action. It is known, however, that certain oils, or rather combinations of oils, are applicable to the treatment of certain ores while others are only remotely so.

These oils, generally in mixtures of one sort or another, have been employed as flotation oils; namely, coal tar and fractions from the distillation of coal, such as coal creosotes; castor oil (mixed in small amount with kerosene or burning oil); eucalyptus oil; pine oil; pine tar; pine-tar oil; rosin and rosin oil (used for the residic acid there in); wood creosote and other products obtained in the destructive distillation of wood, such as pyroligneous acid; petroleum products of different kinds when mixed with a small proportion of the wood oils or some of the coal-tar products.

Although certain oils have all the inherent properties which would suggest their applicability as flotation oils, the fact they are prohibitively costly must act as a strong deterrent either for their use or investigation.

In the United States the oils derived from the pitch pine have given the most satisfactory results on a commercial scale; whereas in Australia, which country is in the van in flotation to-day, the essential oil of eucalyptus has been the most successful. Recent commercial practice has shown that oils of mineral origin promote the best recovery in the case of copper ores, and that oils of vegetable origin, such as the pine oils, turpentine, wood tars, and creosotes are conducive to the best recovery in the case of galena and zinciferous material.

Broadly stated, flotation oils may be classed as "frothing" oils and "collecting" oils. There is at times some difficulty in grasping the distinction between frothers and collectors as such, for one oil in itself may, and often does, possess both frothing and collecting properties. The action of a frothing oil is such as to produce froth in greater or less amount, dependent on the frothing power of the oil. A collecting oil has a collecting power for sulphides in preponderance over its frothing action, being therefore, so to speak, a poor frother; a collecting oil may have simply a collecting action and little or no frothing action. As stated in

the foregoing, some oils combine both the properties of frothing and collecting in variable degrees of each. In the flotation parlance then, the classification is given: (1) Frothing oils; (2) collecting oils.

FROTHING OILS

The most successful frothing oils include the pine oils, cresylic acid, and turpentine and other pyroligneous products from the distillation of wood—notably methyl alcohol. The coal tar phenols and their near derivatives, and almost or all of the so-called essential oils are good frothers. The essential oil of eucalyptus finds favor, particularly in Australian practice, on account of relatively low cost and immediate supply. Castor oil, to which reference has already been made, when mixed 1:4 with kerosene has found application. The more volatile products of petroleum, including kerosene and gasoline, have been successful frothing oils.

On some ores crude pine tar combines the properties both of frothing and collecting; on other ores it is necessary to enrich the pine tar with some such oil as turpentine, pine oil, or wood creosote. Unquestionably, pine oil (steam refined or crude) is the best frothing agent known; however, generally the selective action is not positive and marked, and the concentrates will contain gangue in considerable amount. Experiments in this laboratory indicate that cresylic acid is particularly adapted to the flotation of zinciferous material, exhibiting both good frothing and selective properties.

COLLECTING OILS

So-called mineral oils and tar oils do not generally form a good flotation froth, but have a marked selective action on the sulphide minerals. Among the mineral oils are included the following: asphaltum base, crude petroleum, refined oil, gasoline, burning oil, creosol and coal tar and coal-tar creosotes. Oils derived from the destructive distillation of wood, such as wood creosotes, pyroligneous acid, and the like, are found to give the best recovery on galena and zinciferous material; coal-tar products are better adapted to the successful flotation of copper bearing minerals.

It is found that thick oils tend to form viscous, coherent flotation concentrates, while thin oils form less coherent masses. The action of coal tar in stiffening a weak, ephemeral froth is indicative of the former. In general the essential oils give a coherent froth and satisfactory extraction; oils like oleic acid or candle-maker's red oil, petroleum, and lubricating and engine oils have a strong tendency to produce heavy, thick granules which will not float. Oleic acid has a well-marked power to float silica.

Other Reagents in Flotation

The chemicals used in connection with oil flotation include the following: sulphuric acid, bichromates, permanganates, alkaline chlorides, alkaline sulphates and bisulphates, cupric sulphate, ferric sulphate, aluminium sulphate, thiosulphates and sulphites, organic electrolytes, such as tartrates, citrates, and citric acid, and others almost ad infinitum. Generally the purpose of other reagents than oil is to aid and abet a preferential flotation between the sulphide minerals or in some cases to effect a better separation of mixed sulphides from gangue material, unless indeed they be employed to counteract the deleterious action of certain soluble constituents in either the ore treated or in the water used, or both.

Recent commercial practice indicates that the use of sulphuric acid can be dispensed with if the proper oil combination can be found. Callow* very appropriately

*Bull. A. I. M. E., Dec., 1915, p. 2321.

remarks that the same results can be obtained in an alkaline or neutral pulp as in an acid one. Many mills have come to the use of almost no acid or even to an alkaline electrolyte; this latter promotes good recoveries in the treatment of pyrite as well as other minerals at times.

Experiments performed here on a 60-mesh product from the Joplin district containing pyrite and galena in a calcareous gangue show the following:

1. Potassium dichromate will deaden galena and permit the flotation of the pyrite—a true preferential flotation.

2. Alkaline sulphates, i.e., sodium and potassium sulphates, promote the production of clean concentrates; the same is true of ferric sulphate $\text{Fe}_2(\text{SO}_4)_3$.

3. Ferrous sulphate, FeSO_4 , and cupric sulphate were very harmful to the successful flotation of this particular product, flotation being practically impossible in their presence.

From these results and others of the same nature it is seen that it is of cardinal importance to ascertain the nature of the soluble constituents of the ore and also the nature of the water used in the flotation; proper precautions must be taken if anything of a deleterious character is present.

There seems to be considerable weight in the statement "a particular oil for a particular ore." In other words, no given oil can generally be employed effectively on a number of different ores. Further, different samples of the same oil will produce radically different results, as a small variation in homogeneity often engenders considerable difficulties. Usually acid will produce a concentrate free from silica, but its use can probably be just as well avoided.

Sizing.—Careful screen analysis with subsequent microscopic examination or wet analysis shows that in slimes, for instance, the bulk of the values obtain in the material that passes the finer meshings. And it is believed that the ordinary run of ores require grinding to 60-mesh at least for oil flotation treatment.

Microscopic Examination.—The microscope is an invaluable aid in flotation work of an experimental nature, effecting a large saving of time which would otherwise be consumed in tedious and long drawn-out quantitative analysis. Casual inspection under the microscope will give at once a pretty definite idea of the grade of the tailing, middling, or concentrate. Quantitative analysis is, of course, the final criterion on which to base results. The binocular microscope is more satisfactory than any other type.

Results of Experiments on a Settled Product from the Joplin District.—Additional experiments performed on the product mentioned above warrant these conclusions:

1. A satisfactory oil mixture would be: 5 parts wood creosote, 2 parts pine oil, 0.5 parts coal tar; or part of the pine oil may be replaced by soap solution in variable amount, thus reducing the cost.

2. A pulp dilution of 3.5:1 or 3:1 works well; the general run of data indicate that the pulp could be run as thick as possible within limits which would be occasioned by the fouling of the operation due to clogging of the test machine.

3. The action of the coal tar here is to stiffen the froth which for any reason might become weak.

4. The effect of temperature was practically nil.

5. Sulphuric acid does not increase the tenor of the concentrates.

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Coal and Coke Efficiency in Blast Furnace Operation

BY BIRGER F. BURMAN

Coal Efficiency

The factors that principally influence the value of a certain kind of coal for the blast furnace are ash and sulphur. Phosphorus, of course, must not be present above certain small limits, but as there are no means by which any part of the same can be eliminated, it will not here be considered. The only thing left for the coal-mine superintendent to do is to watch for the limit, stipulated by the coke maker; if the phosphorus content should be too high, the coal must be used for some other purpose.

With the ash and sulphur it is different. There is some chance of diminishing the amount of these elements in the coal, thereby making it more suitable; and as both ash and sulphur are quite deleterious in the blast furnace, any fraction of 1 per cent of either, that can be kept out, means money saved in the operation. It is, therefore, important to be on a constant guard against such materials, and as the mine is the proper place for improvements, a system of efficiency should there be inaugurated. It will then be easier for the mine superintendent to furnish a product, that ought to command a higher price than before.

It is not the scope of this article to go into the subject of coal washing, etc., or any necessary means by which the ash and sulphur constants may be lowered. No such work of improvements, however, can be made without some kind of an indicator, whereby it can be judged and the interest of the men kept up. Such an indicator is the "efficiency" percentage.

For any comparison there must be a standard. In this case local conditions will govern the nature of the same and an analysis may be adopted which is a fairly true average at the coal heretofore mined. Extremes should be excluded and only reasonable analyses for maximum and minimum amounts of ash and sulphur be adopted. For instance, coal from a certain mine gave the following analyses (dry) during a year's time:

	Ash, per Cent	Sulphur, per Cent
Maximum . . .	12.00	1.35
Minimum . . .	8.00	0.75
Average . . .	10.00	1.05

This analysis may be adopted as a standard for next year's work and by assuming the minimum to represent 100 per cent efficiency, the "efficiency" of any other percentage composition may be figured out as in the following examples:

Example 1

A certain coal analyzed 10.37 per cent ash and 1.13 per cent sulphur.

To find its "efficiency" we have an increase in ash of $10.37 - 8 = 2.37$ per cent (over the minimum of the preceding year).

$$(2.37 \times 100) \div 8 = 29.625.$$

Hence $100 - 29.625 = 70.37$ per cent is the "efficiency" for ash.

The increase in sulphur percentage over the minimum of the preceding year is $1.13 - 0.75 = 0.38$.

$$(0.38 \times 100) \div 0.75 = 50.667.$$

Hence $100 - 50.667 = 49.33$ per cent is the "efficiency" for sulphur.

Example 2

A certain coal analyzed 7.92 per cent ash and 0.70 per cent sulphur. To find its "efficiency" we have a de-

crease in ash below the minimum of the preceding year of $8 - 7.92 = 0.08$ per cent.

$$(0.08 \times 100) \div 8 = 1.$$

Hence $100 + 1 = 101$ per cent is the "efficiency" for ash.

The decrease in sulphur is $0.75 - 0.70 = 0.05$.

$$(0.05 \times 100) \div 0.75 = 6.667.$$

Hence $100 + 6.667 = 106.67$ per cent is the "efficiency" for sulphur. With the shipment the following report is forwarded to the coke ovens:

COAL SHIPMENT NO.			
From mine:			
Number of cars:			
Weight in tons of 2000 lb:			
Date of shipment:			
Analysis (dry): Volatile matter		per cent	
Fixed carbon		per cent	
Ash		per cent	
S		per cent	
P		per cent	
Efficiency: For ash		per cent	
For sulphur		per cent	
Total		per cent	

Coke Efficiency

The value of a certain coke for blast-furnace operations is dependent on its chemical analysis, and its physical structure. As for the moisture, this may be neglected as far as it concerns the operation of the blast furnace, especially, where the gases are washed; however, it should be recorded for the sake of giving an idea of how much water is unnecessarily handled and paid for; also for the sake of determining the weight of dry coke used.

Phosphorus is, of course, of great importance, but as there is such a slight chance, if any, to diminish it, it may be safely left out in any system of coke efficiency. However, it should be noted as a record and as a check on the coal mine.

While it would be desirable to have a constant composition of the ash, there is no way by which this can be accomplished. Therefore, to record the *detailed* analysis of the ash would be of no value.

The actual value of a coke is dependent on the amount of available fixed carbon it can furnish the blast furnace, consequently the coke should be high in fixed carbon and low in ash. But in order to reach a high grade of perfection in this respect, it will be necessary to pay strict attention to moisture and volatile matter.

The object of an efficiency system, as outlined below, should be not only to improve the quality of the coke but to keep it at the same uniform analysis and physical structure. Uniformity is just as important for the blast furnace as quality because expensive disturbances are caused by a variable quality of the stock and not by a uniform stock, even though poorer.

The efficiency system being merely an indicator will give no rules or methods of working in order to keep up or improve the quality of coke produced. It will be entirely up to the coke-oven superintendent to do this. As he will be in constant communication with the coal-mine superintendent, he can demand the proper kind of raw material; after that his attention must be directed on the ovens.

The following factors are more or less subject to improvements:

- Physical structure of the coke.
- Volatile matter on the decrease.
- Fixed carbon on the increase.
- Ash on the decrease.
- Sulphur on the decrease.

Regarding the physical structure it is entirely a matter of judgment and practical experience to properly define its nature and value. Certain prearranged rules in this respect must therefore be established.

As was said under coal efficiency, there must be a

standard of comparison. Such a standard may here be the average analysis of coke (dry) for a considerable length of time, say one year, with fair maximum and minimum values defined. As an example the following analyses may be given:

	Maximum, per Cent	Minimum, per Cent	Average, per Cent
Moisture	3.50	1.50	2.50
Volatile matter	2.00	1.20	1.60
Fixed carbon	86.40	84.30	85.35
Ash	13.80	12.50	13.00
Sulphur	1.05	0.75	0.90

This analysis may be used for the coming year and by giving 100 per cent efficiency to:

Fixed carbon for its maximum	86.40 per cent
Moisture for its minimum	1.50 per cent
Volatile matter for its minimum	1.20 per cent
Ash for its minimum	12.50 per cent
S for its minimum	0.75 per cent

the efficiency of any other analysis may be determined.

EXAMPLE

A certain coke gave the following analysis:

Moisture	2.59 per cent	
Volatile matter	1.90 per cent	
Fixed carbon	85.78 per cent	on dry coke
Ash	12.32 per cent	100.00 per cent
Sulphur	0.83 per cent	

To find its efficiency we proceed as follows:

Moisture:		
Increase: $2.59 - 1.50 = 1.09$		
$(100 \times 1.09) \div 1.50 = 72.67$		
Efficiency: $100 - 72.67 = \dots$		27.33 per cent
Volatile matter:		
Increase: $1.90 - 1.20 = 0.70$		
$(100 \times 0.70) \div 1.20 = 58.33$		
Efficiency: $100 - 58.33 = \dots$		41.67 per cent
Fixed carbon:		
Efficiency: $85.78 \times 100 \div 86.40 = \dots$		99.28 per cent
Ash:		
Increase: $12.32 - 12.50 = -0.12$		
$(100 \times 0.12) \div 12.50 = 0.96$		
Efficiency: $100 - 0.96 = \dots$		99.04 per cent
Sulphur:		
Increase: $0.83 - 0.75 = 0.08$		
$(100 \times 0.08) \div 0.75 = 10.67$		
Efficiency: $100 - 10.67 = \dots$		89.33 per cent

If the moisture, volatile matter, ash and sulphur should be of lower percentages than those given for the standards, the decrease in each case will, of course, add a corresponding percentage to the 100 per cent. For instance, if the ash content was 12.02 per cent. the decrease would be 0.18 and the efficiency $100 + 100 \times 0.18$

$\frac{12.20}{12.50} = 101.48$ per cent. The total analysis efficiency of the coke given in the example above may be considered to equal the sum of all the four efficiencies divided by 4. The total analysis efficiency is therefore $\frac{41.67 + 99.28 + 99.04 + 89.33}{4} = 82.32$ per cent. The

moisture efficiency is treated separately.

The physical structure may be given factors according to certain prearranged rules, each factor representing the efficiency given by the factor. It is not necessary to stipulate so many factors; only the factors 100-90-80-70-60-50 will do. These figures will then also stand up for 100-90-80-70-60-50 per cent efficiencies respectively.

Every coke shipment is sampled and analyzed. The following form for reporting the analysis may be used:

ANALYSIS OF . . . HOURS COKE			
From coke shipment No.	Coal shipment No.		
Number of cars:			
Weight in tons of 2000 lb:	tons		
Moisture		per cent	
Volatile matter		per cent	
Fixed carbon		per cent	
Ash		per cent	per cent on dry coke
S		per cent	per cent
P		per cent	per cent

(Moisture is driven off without determination and coke is analyzed "dry")

ON COKE SHIPMENT No.

	Wet	Dry
Moisture (average of the daily analyses)	2.50%	1.60%
Volatile matter Sulphur in combustibles not Fixed carbon } included.	82.32%	85.35%
Ash	12.53%	13.00% 99.95%
Phosphorus (remaining in the ash)	0.024%	0.025%
Sulphur (remaining in the ash)	0.130%	0.900%
Sulphur (remaining in the combustibles)	0.750%	
Total	100.014%	

Ash—12.684, figured on wet coke—analyzed:

[illegible]

Figures as shown have been put in only for exhibition. Sulphur is considered to be present as CaS, therefore CaO found should be adjusted accordingly.

$$P.O. = 2.29 \times P.$$

$$\text{CaS} = 2.25 \times \text{S}$$

$$\text{Ca in CaS converted into CaO} = 1.75 \times S.$$

In order to determine the fluctuations in value of coke, it is necessary to figure out the relative value of coke used. In this way it will be possible to determine fairly well the losses due to improper quality of the coke.

Standards will be necessary here as in anything else for making comparisons. Averages for some previous period, say one year, may be adopted; but the figures given below must be understood to be merely used for illustration purposes; they should be adjusted to suit local conditions.

Standards:

- | | |
|---|--------|
| 1. Cost of coke per ton of 2000 pounds, here assumed to be | \$2.20 |
| 2. Cost of limestone per ton of 2240 pounds, here assumed to be | 1 10 |
| 3. Cost of sand* per ton of 2240 pounds, here assumed to be | 1 10 |
| *This term stands for acids. | |
| 4. Cost of slag from tapping to its disposal by the railroad per ton of 2240 pounds, here assumed to be | 0 20 |
| 5. Amount of pure fixed carbon to melt the slag: = 0.22 pounds per pound of slag. | |
| 6. Ratio of acids to bases in the slag here assumed to be 1. | |
| 7. Analysis of limestone, see below. | |
| 8. The relative value of any coke shall be determined by the cost per ton of 2000 pounds of pure available fixed carbon to the furnace. | |
| 9. The relative value of coke, ash and slag from flux uncleaned into the furnace slag. | |

Example:

A certain coke (wet) gives the following analysis:

Moisture	2.50%	[SiO ₂]	6.02%
Volatile matter	1.56%	Al ₂ O ₃	3.61%
Fixed carbon	82.52%	CaO	0.666%
Ash	12.53%	MgO	0.24%
P (remaining in the ash)	0.024%	FeO	1.80%
S (remaining in the ash)	0.130%	P ₂ O ₅	0.053%
S (remaining in the combustibles)	0.750%	CaS	0.293%
		Total	12.684%

Going to the $sl_{3\sigma} = 12.684 - 0.055 = 12.629$

Standard analysis of limestone used:

SiO ₂	5.80 per cent	9.80 per cent acids
Al ₂ O ₃	4.00 per cent	
CaO	46.54 per cent	
MgO	2.78 per cent	50.21 per cent bases
Fe ₂ O ₃	0.89 per cent	
P ₂ O ₅	0.023 per cent	0.01 per cent
CaS	0.340 per cent	0.15 per cent
CO ₂	39.63 per cent	
Total	100.003 per cent	

REPORT NO. ON COKE CONSUMED AT BLAST FURNACE NO.

During the week ending ...

Date _____

[illegible]

Going to the slag: $9.80 + 50.21 + 0.34 = 60.35$

Limestone required to each 100 pounds of fuel burnt = y pounds

SiO ₂ . . .	6.02 + 0.0580y	Acids	= 9.63 + 0.0980y
Al ₂ O ₃ . . .	0.61 + 0.0400y		
CaO . . .	0.666 + 0.4654y		
MgO . . .	0.24 + 0.0278y	Bases	= 2.706 + 0.5021y
FeO . . .	1.80 + 0.0089y		
CaS . . .		CaS	= 0.293 + 0.0034y
		Total	12.629 + 0.6035y

$$9.63 + 0.0980y = 2.706 + 0.5021y$$

$$y = 17.13 \text{ pounds of limestone}$$

$$\text{Slag formed} = 12.629 + (17.13 \times 0.6035) =$$

$$\text{Sulphur present in coke.}$$

$$\text{in limestone } 0.1713 \times 0.15 =$$

$$\text{Sulphur in slag (per cent)} 90.57 \div 22.97 =$$

$$\text{Total per pound of fuel burnt:}$$

$$\text{Limestone}$$

$$\text{Slag}$$

$$\text{Carbon to melt the slag } 0.2297 \times 0.228 =$$

$$\text{Leaving for furnace available } 0.8252 - 0.0524 =$$

$$\text{Carbon efficiency of coke}$$

$$\text{Cost (sulphur not considered):}$$

$$\text{The cost of coke } \$2.30 \times (1 + 0.7728) =$$

$$\text{The cost of stone } \$1.10 \times (1 + 1.12) \times 0.1713 \div 0.7728 =$$

$$\text{The cost of slag } \$0.20 \times (1 + 1.12) \times 0.2297 \div 0.7728 =$$

$$\text{Cost per ton of 2000 pounds of pure available carbon.}$$

$$\text{Cost per ton of 2000 pounds of coke } 3.118 \div (1 + 0.7728) =$$

COST (SULPHUR CONSIDERED)

Only a limited amount of sulphur can be kept in solution by the blast furnace slag without danger of being absorbed by the pig iron. Often the amount of slag is quite sufficient to take care of the sulphur, brought in by the fuel, but more often extra slag has to be provided for. This is quite an item, as will be seen from the following.

A new standard has to be adopted, namely, the amount of sulphur the slag shall be allowed to carry. This will here be assumed to be 1.40 per cent for our special example.

22.97 pounds of slag satisfy $0.2297 \times 1.40 =$	0.3216 S
Sulphur present (see above) . . .	0.9057 S
Net sulphur for which outside slag must be provided	0.5841 S
(See Coke and Limestone, Supplement, Case V.)	
Requirements: Slag produced	46.70 pounds
Fixed carbon consumed 18.23 $\times 0.5841 =$	10.65 pounds
Stone consumed 19.36 $\times 0.5841 =$	46.35 pounds
Sand or its equivalent 32.07 $\times 0.5841 =$	18.73 pounds
Total per pound of fuel burnt:	
Fixed carbon	0.7728 - 0.1065 =
Limestone	0.1713 + 0.4635 =
Sand or its equivalent	0.1873 pounds
Slag	0.6967 pounds
Carbon efficiency of coke	66.63 per cent
Sulphur in coke	0.88
Sulphur in stone $0.6348 \times 0.15 =$	0.0952
	0.9752 S
Sulphur in slag (per cent)	97.52 $\div 69.67 =$
The cost of coke	\$2.30 $\times 1 =$
The cost of stone	1.10 $\times (1 + 1.12) \times 0.6348 \div 0.6663 =$
The cost of sand or its equivalent	1.10 $\times (1 + 1.12) \times 0.1873 \div 0.6663 =$
The cost of slag	0.20 $\times (1 + 1.12) \times 0.6967 \div 0.6663 =$
Cost per ton of 2000 pounds of pure available carbon	\$4.701
Cost per ton of 2000 pounds of coke $4.701 \div (1 + 0.6663) =$	3.132
Cost due to sulphur alone (no cost for reduction included) per ton of 2000 pounds	
of coke $3.132 - 2.410 =$	0.722

The report on coke consumed as shown at the bottom of page 139 is filled out every day and at the end of the week completed on the average analysis.

AVERAGE ANALYSIS FOR THE WEEK:

	Dry	Wet	
Moisture			SiO ₂
Volatile matter			Al ₂ O ₃
Fixed carbon			CaO
Ash			MgO
P. remaining in the ash		Total ash	FeO
S. (remaining in the ash)		Total S	P ₂ O ₅
S. remaining in the combustibles			CaS
Total			
Slag produced per unit of coke burnt			
Sulphur in slag		per cent	Sulphur not considered
Carbon efficiency			
Cost per ton of pure available carbon			
Cost per ton of coke			
Cost per ton of coke due to sulphur alone			

(To be concluded)

An Electrically Heated Bomb Furnace

BY D. F. CALHANE AND H. A. LAVENE

Certain classes of chemical reactions are carried on under pressure in sealed glass tubes. The most common of these reactions are those for the determination of chlorine, bromine, and iodine in organic substances by heating them under pressure with nitric acid.

The type of furnace most generally used consists of from eight to ten iron pipes that are fastened in a frame, enclosed by an air bath that is heated by gas ring burners. Channels around the pipes for air circulation provide for even heating. To protect against injury from the explosions of the tubes that frequently occur, there is a swinging triangular door at the ends. The rate of heating is determined by the size of the gas flame.

This furnace has several disadvantages, such as the following: With gas heating it is more or less difficult to bring the furnace up slowly and evenly to full heat and then maintain a constant temperature for a considerable interval of time. Varying gas pressure and air drafts seriously interfere with even heating. The explosion door does not work to full satisfaction. It allows of drafts; and particles of glass from the explosion of tubes in the top pipes, are reflected back into the lower tubes, causing these to explode. Glass particles from exploding tubes in lower pipes are sent out into the room from the fact that the door swings too far out from the impact with the longer lever arm. The gas flames are invariably put out by an explosion, causing delay.

For these reasons, the electrically heated furnace described in this article was designed and constructed. This does away with all gas troubles, and the new type of door devised eliminates dangers from flying glass particles.

In the construction of the furnace, eight small iron pipes are arranged around the central larger pipe, in a circle. These eight pipes are of $\frac{3}{4}$ -in. standard wrought-iron tubing, and the central pipe is $1\frac{1}{2}$ -in. tubing. The pipes are 25 in. long. A pin is inserted near the end of the pipes and a corresponding slot is cut in the retaining frame, thus permitting the removal of the tubes from the furnace for unsealing the contained glass tube.

The heating element is nichrome wire of the ribbon type. This is wound on insulated iron pipes that form the outer and inner winding frames. The outer pipe is a 25-in. section of 6-in. steam pipe, and the inner pipe is a 23-in. length of the standard $1\frac{1}{2}$ -in. wrought-iron tubing. For insulating the heating wire from the iron pipes, a $\frac{1}{8}$ -in. layer of alundum cement is used. The mass of iron gives good inertia to sudden possible heating variation, and thus makes for even temperature rise. The windings on the outer and inner frames are in series, giving the simplest electrical arrangement. The inner winding frame is easily removable through a detachable plate in the retaining frame. The wire on the inner frame is wound over the alundum-cement covering and then covered with a thin outer layer of the same cement. Over all is a jacket of thin sheet iron to protect the winding from mechanical injury.

In the case of the outer winding, the wire is wound with $\frac{1}{2}$ -in. space between the convolutions and covered with a thin layer of cement to protect from oxidation. A removable heat insulating muffle of alundum cement composition comes next, and around this a jacket of magnesia pipe insulation, such as is commonly used for steam-pipe covering. The air film between the two jackets will be a more efficient heat insulator than a solid joint. The desirable thickness of these insulating jackets was given from those used in another furnace

Improvements to Smelter.—Improvements to cost \$100,000 will be made to the Tacoma smelter of the American Smelting & Refining Co.

of same type, designed and operated here for various heating purposes. The general appearance of the heating elements is shown in Fig. 1.

In devising an explosion door an attempt was made to avoid the troubles that arise with the use of the hinged, triangular type of ballistic door.

When a reaction tube explodes in the furnace, the gas pressure sends the glass fragments out and smashes them against the end door. So the door has to relieve the gas pressure and withstand the blow of the glass fragments. The usual type of door is hung on the furnace at an angle of 30 deg., with the idea that the force of the explosion will carry the door out to 45 deg., where the law of incidence and reflection angles will cause the glass fragments to be entirely deflected down to the supporting bench on which the furnace stands. The failure of the door to act properly is due to two reasons. One is that the force of the blow varies, and secondly that the lever arm is shorter in case of an explosion from the upper tubes than it is where an explosion from the lower tubes occurs. These surmises were tested experimentally as follows: A rifle loaded with scatter shot was fired through the different tubes against the swinging door. Beforehand the other seven tubes, the wall behind the door, and the top of the table beneath, were covered with sheets of paper. The different paths of the shot could thus be registered on the paper. There were eight tubes in the furnace, two in a row, and four rows high.

In the case of the two middle tubes, the door worked fairly well. No particles of shot were deflected back into the other pipes and none were projected out into the room. In the case of the two lower tubes, nearly all the shot went out into the room. When fired from the top tubes it was found that nearly all the shot was deflected into the next tubes lower down. The effect of this in exploding other tubes heating in the lower rows is easily imagined. These experiments showed very conclusively that the swinging, ballistic type of door is unsatisfactory. After some study, a pop valve type of door was designed. This would consist of an iron cap, $\frac{1}{4}$ in. thick, and 11 in. in diameter, with a $\frac{1}{8}$ -in. flange $1\frac{1}{4}$ in. deep on the rim. This cap fits over each end of the furnace and supports the door mechanism. The door frame consists of an iron, flat ring, 3 16 in. thick and $8\frac{3}{4}$ in. in diameter that is hinged to the cap. Secured to this door ring are two cross strips of $\frac{1}{4}$ -in. x $\frac{3}{8}$ -in. stock, whose ends are bent down to form feet that are screwed to the ring. In this way, $\frac{3}{4}$ -in. clear-

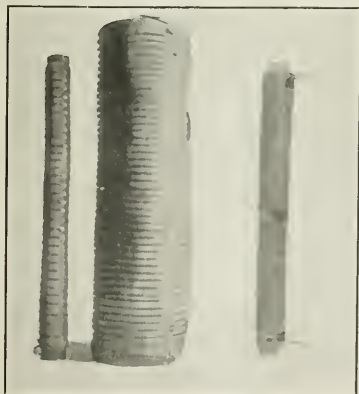


FIG. 1—HEATING ELEMENTS

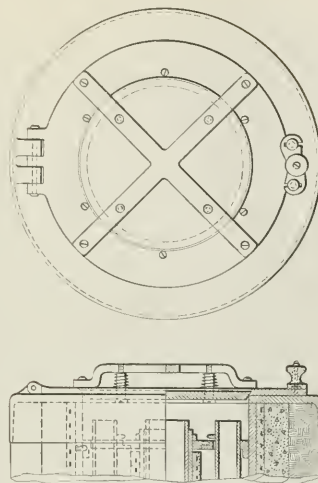


FIG. 2—DRAWING OF DOOR AND FURNACE END

ance between the under side of the cross strips and the door proper is attained.

The door itself is an iron disk 6 in. in diameter and 5 16 in. thick. Four screws secured to the cross strips pass four holes in this disk with a $\frac{1}{16}$ -in. clearance. Four conical springs on the shank of these screws, exert tension on the disk, which has a 30-60-deg. bevel around it, forming a shoulder that allows the disk to find its own set against the inner edge of the flat ring, and thus make a tight closure under the spring tension. At whatever point the disk is struck, it will give and release the pressure against the spring tension, returning instantly to its fixed position. The whole mechanism is fastened to the end caps by a catch arrangement.

The furnace is supported on feet, at a height of 6 in. from the table, and rests in two semicircular iron hoops secured to the supporting frame work. The furnace is tilted by making two of the feet $\frac{3}{4}$ in. shorter than the others.

A face and sectional drawing of the door and furnace ends is given in Fig. 2; also a view of the completed furnace in Fig. 3.

The next problem was to calculate the input sufficient to reach a maximum desired temperature at a desired rate. The upper temperature limit was set at 350 deg. C. that is to be attained in four and one-half hours. The rate of heating for the kind of work the furnace is to do must be even and fairly slow, and under good control.

Until very recently there was no path open to a satis-

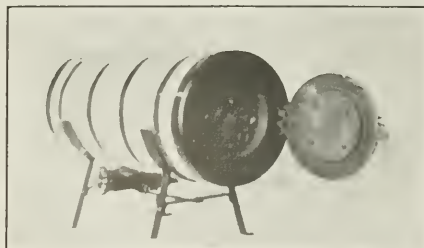


FIG. 3—COMPLETE FURNACE

factory solution of such a problem, and cut and try was the only course. After a study of the papers by C. Hering¹ and I. Langmuir² a set of principles was selected from them that appeared to lead to a satisfactory approximation of the results desired. These principles deduced in these papers, although concerned with the design of large furnaces, might be also applied to small ones.

1. In a rather approximate calculation of this sort the heat losses by conduction only will be considered. In a furnace of this type, radiation and convection losses will be very small.

2. The wattage input is always balanced at equilibrium by the heat loss through the walls.

3. The flow of heat through a furnace wall is almost exactly analogous to the flow of electricity. The different components of the wall offer resistance to the flow of heat just as certain media do to the flow of the electric current. The total resistance of different layers is the sum of their separate resistances if in series. So the electrical formula $R = r + r' + r''$ applies, in which R is total resistance and r, r', r'' the separate resistances.

The volt or pressure factor is comparable to the temperature. The ohm is similar to the thermal resistance unit or "thermal ohm." The ampere is likened to the amount of heat flowing. The analogy breaks in that the temperature coefficient of the thermal ohm has a negative sign.

4. The thermal ohm is that unit of resistance requiring a drop of 1 deg. C. for 1 watt of heat flow.

5. From the above the ordinary resistance formula may be applied:

$$R \text{ (resistance)} = \frac{L \text{ (depth of wall)} \times r \text{ (spec. resistivity)}}{S \text{ (average cross-section)}}$$

6. Carrying out the analogy of heat and electricity still further, Ohm's law may be applied to represent the flow of heat.

$$T \text{ (temp. drop between inner and outer surfaces)}$$

$$W \text{ (heat flow in watts)} = \frac{T}{R \text{ (thermal resistance in thermal ohms)}}$$

7. From (5) and (6) we get by substitution

$$W = (TS)/(lr)$$

8. According to Nusselt, the thermal resistance is halved for every 273 deg. rise in temperature. Therefore the higher the temperature, the lower the resistance, and the greater the heat loss.

9. A joint or a crack makes a very good heat insulator. Still air is a poor heat conductor. A porous substance is a good heat insulator as it contains a large amount of still air. The effect of contact resistance is met with when heat flows from one medium to another.

10. Waste space in a furnace should be avoided. The smaller the insulating air space the better.

11. The average cross-section of a wall will be figured as the arithmetical average of the surface of the inner and outer walls, or

$$\frac{1}{2} [S \text{ (area outer surface)} + S \text{ (area inner surface)}]$$

The dimensions of the furnace are as follows:

Length of outside winding frame.....	= 25 in.
Inside diameter of outside winding frame.....	= 6.125 in.
Outside diameter of outside winding frame.....	= 6.625 in.
Outside diameter of alundum insulation.....	= 7.125 in.
Outside diameter of muffle insulation.....	= 8.875 in.
Outside diameter of magnesia covering.....	= 11.000 in.
Length of inner winding frame.....	= 23 in.
Diameter of inner winding frame.....	= 2.25 in.

From the foregoing principles and dimensions the thermal drop through the walls was determined.

The constants for the thermal resistances of the materials in the furnace insulation were corrected to represent the average resistance between 25-350 deg. C. Most of the constants were given in Hering's tables, *op. cit.*, between limits 20 deg.-188 deg. C. We have as the corrected resistivities between 25 deg.-350 deg. C.

Iron.....	0.8
Magnesia covering.....	500.0
Asbestos cement.....	120.0
Still air.....	100.0
Alundum cement.....	15.0

A typical calculation of the heat loss from the outer winding through the insulating walls will suffice to show the general method of approximating this value. The heat flow is from wires to asbestos muffle, to magnesia covering out to outside air. Asbestos muffle:

Average surface = $\frac{1}{2}(S + s)$, in which S and s are the areas of outer and inner surfaces respectively.

$$1. \text{ We have then average area} = \frac{\pi DL + \pi dl}{2} =$$

$$3.1416 \times 7.125 \times 25 + 3.1416 \times 8.875 \times 25 = 630 \text{ sq. in.}$$

$$2. R = \frac{\text{depth} \times \text{sp. resist.}}{\text{av. cross-section}} = \text{resistance of wall to flow of heat.}$$

$$\frac{0.875(\text{depth}) \times 120 \text{ sp. resist.}}{630 \text{ av. cross-section}} = 0.167 \text{ thermal ohm.}$$

Solving again by (1) for magnesia covering we have 781 sq. in. for average cross-section. Applying this value in (2) equation we obtain 0.678 of a thermal ohm.

The total resistance to heat flow of outer covering will be R for asbestos plus R for magnesia, or $0.678 + 0.167 = 0.845$ thermal ohm, the total resistance. Applying from principle (6) the formula:

$$W = \frac{T}{R}, \text{ or loss in watts, } W \text{ equals total temperature drop, } T \text{ divided by thermal resistance}$$

$$\frac{350^\circ \text{ (inside temperature)} - 50^\circ \text{ (outside temperature)}}{0.845 \text{ (total resistance of insulation)}} = \frac{300}{0.845} = 355 \text{ watts.}$$

Similarly, the loss from inner winding was calculated to be 205 watts. The total thermal resistance from inner winding out was, air space, 0.642; thin alundum and sheet iron on inner winding tube plus iron of outer 6-in. pipe, plus $\frac{1}{4}$ -in. alundum on outer pipe, 0.005 thermal ohm. As above, outer coverings, 0.845 thermal ohms. Total, 1.492 thermal ohms. 300 over 1.492 = 205 watts.

Loss from both ends through media of iron frame or pipe, plus air space, plus iron door, was 150 watts.

Total loss of heat from furnace was then

Heat loss from outer element.....	355 watts
Heat loss from inner element.....	205 watts
Heat loss from ends.....	150 watts

710 watts at 350 deg.

Next, it is desirable to know the number of watts that expended in the furnace will raise its temperature 1 deg. C. This gives the heat equivalent of the furnace. There are 80 lb. of iron in the construction and 10 lb. of alundum. The specific heat of iron from 25 deg.-350 deg. is 0.135; the specific heat of alundum is likewise 0.198. The iron equivalent is $80 \times 454 \text{ (mass in grams)} \times 0.135 = 4903$ calories. The heat equivalent for alundum is $10 \times 454 \times 0.198 = 899$ calories. This gives a total of $4903 + 899$, or 5802 calories.

The time it will take the furnace to rise to a given temperature will be determined by the energy supplied per second, energy lost per second, and the heat equivalent of the furnace.

The heat equivalent has been figured above, and the energy lost per second at certain temperatures has been

¹Carl Hering, Heat Insulation of Furnace Walls. 1910-1912 Met. & Chem. Engineering.

²Langmuir, Melick & Adams. Flow of Heat Through Furnace Walls. 1913. Trans. Am. Elec. So. Vol. 24, p. 53.

calculated. The supply of energy is to be determined. At 350 deg. temperature for the inside of the furnace the loss has been calculated to be 710 watts through the walls. Then the approximate time to rise to 350 deg. C. would be figured as follows:

$$\begin{aligned} \text{Time in hours} &= \frac{350 \times 5802 \times 4.2 \text{ (cal. to watts)}}{3600 \times (\text{input} - \text{aver. loss}) \text{ per sec.}} \\ &= 4.3 \text{ hours.} \end{aligned}$$

If we figure on an input of 900 watts and a loss of 710 watts at 350 deg., the average loss from room temperature up to 350 deg. will be 355 watts. This gives 4.3 hours, as approximate time of heating with 900 watts. From this it will be seen that 900 watts is a desirable input, that allowing for temperature coefficients in windings will raise the furnace to 350 deg. in about four and one-half hours. This was found to be the case in actual test as shown later.

In winding the furnace, allowing $\frac{1}{2}$ in. between convolutions, and with 24 in. winding surface on outer element, the calculation gave 98 ft. for outer and 20 ft. for inner tube. The ratio of masses of outer to inner is as 5 to 1. Total length of wire 118 ft. It was calculated that 120 ft. of $\frac{1}{8}$ -in. ribbon should allow 900 amp. to flow without undue heating of the wire. Accordingly, No. 18 nichrome ribbon wire was chosen from the Driver-Harris specifications. This gave a ribbon nearly $\frac{3}{64}$ in. thick and $\frac{1}{8}$ in. wide.

In winding this wire on the inner tube, which is $2\frac{1}{4}$ in. in diameter gross—that is, including the aluminum insulation—it was first wound in a lathe on a $1\frac{1}{2}$ -in. arbor under sufficient tension to hold the turns in place. The lathe gears were set for a 2-in. thread that gave two turns per inch with $\frac{1}{2}$ in. between turns. On releasing the tension a spring was obtained of exactly $2\frac{1}{4}$ in. diameter. This was slipped over the inner heating element, and twisted until the turns laid tight. A coating of aluminum cement was applied, and over this was wrapped a double layer of thin asbestos paper. The whole element was now covered with a sheath of thin iron to protect the winding from possible injury in withdrawing the heating tubes.

In winding the wire on the outer cylinder, this had to be done by putting the pipe into the lathe and winding on the wire, securing the ends by clamps. Care must be taken not to use too much tension as the aluminum insulation is apt to be cracked off.

In the testing of the completed furnace, a series of four constantin-thermo couples were used, each one being placed in a pipe differently situated in the furnace. These couples could be rapidly read by a master switching arrangement, with a mirror galvanometer,

whose scale was calibrated against the vapor temperatures of different chemical substances.

With an average of 106 volts and 8.2 amp. the furnace reached 350 deg. in four and one-half hours. With an average of 8 amp. and 108 volts the final equilibrium temperature was 450 deg., attained in eleven and one-half hours.

Fig. 4 below gives a heating curve that is averaged from four different heats. This is accurate within 10 per cent.

The explosion doors were tested by heating tubes thinly sealed and carrying as much as 6 c.c. of nitric acid until they exploded. The doors worked very well. Only a fine dust of glass came into the room that was carried out by the acid fumes. To avoid all possible chance of this, sheet iron hoods are slipped over the ends of the furnace. These are 5 in. deep and have a hole in the center $3\frac{1}{2}$ in. in diameter, covered with wire gauze for release of air pressure during explosion. These hoods prevent any glass whatsoever coming into the room, and also muffle the sound of the explosion to a dull rumble, whereas it is ordinarily like a heavy rifle report.

This furnace, with hoods as just described, can be attached to any suitable commercial 110-volt circuit on any bench in the laboratory without causing any trouble to near-by workers.

For regulating the temperature through certain desired intervals, a rheostat was devised with a dial switch, as shown in the cut of the completed furnace. This provides for ten steps in the temperature scale, from 200 to 450 deg. in intervals of 25 deg.

From calculations previously given, it is found that at 200 deg. the wattage supplied to the furnace is 260. At this point the maximum resistance needed is in series with the furnace.

The calculation of this resistance may be performed as follows:

Let E be the supply voltage — 110; also let I denote the value of the current flowing. Wattage desired 260. The resistance of the furnace is $R = 13$ ohms. Desired resistance in the rheostat R' . Then $E = I(R + R')$, or $110 = I(13 + R')$. Also power or wattage $= EI = 260 = RI$. Whence $260 = I \times 13$ and $I = 4.15$ amp. Substituting in equation above — $110 = 4.15 \times (13 + R')$; whence $R' = 13.5$ ohms.

So a length of wire having a total resistance of 13.5 ohms is desired.

Now at 350 deg. heat in the furnace, the wattage input is $710 = EI = RI$, whence $710 = I \times 13$, and $I = 7.4$ amp. Substituting, we have $E = I \times (R + R')$; when $R' = 1.37$ ohms in resistance box. Then the potential fall through resistance box equals from the proportionality law — $E : E' :: (13 + 1.37) : 1.37$; when E' , the drop in resistance box, equals 11.6 volts. The wattage consumed is $11.6 \times 7.4 = 86$ watts. Similarly for lower limit of 200 deg. The current flowing is 4.15 amp. and resistance in box is 13.5 ohms. The potential drop figures 56 volts, and the wattage is $4.15 \times 56 = 232$ watts. This gives maximum heating wire must stand. On the basis of these figures, No. 17 nichrome wire was selected, having 264 ohms per 1000 ft. The box is constructed of sheet iron built on slate slabs; it measures $1\frac{1}{2}$ in. x 4 in. x 7 in. The wire was crimped into a spring $\frac{3}{8}$ in. diameter, giving thirteen turns to the inch, and in each inch of spring there are $1\frac{1}{2}$ ft. of wire. There are ten separate coils, in two rows of five coils each, one row above the other. The various terminals are brought out to brass plugs in a fiber disk and contacts made successively with the various coils by the dial switch.

Electro-Chemical Laboratory,
Worcester Polytechnic Institute.

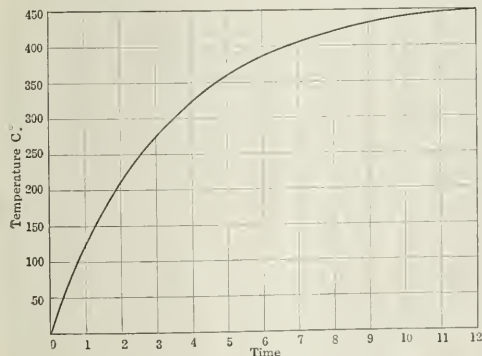


FIG. 4—HEATING CURVE OF FURNACE

The Development in the United States of the Manufacture of Products Derived from Coal

A paper read at the Baltimore meeting of the American Institute of Chemical Engineers, on January 12, 1916.

BY H. W. JORDAN

During 1915 we read statements in the press almost daily which gave the impression that our American chemical industry was wholly unable to manufacture synthetic coal products, and that the only relief in sight was from the wonderful discoveries of a small group of chemical amateurs, who, having patriotically hurled themselves into the situation since the war began, were on the verge of evolving the entire 900 synthetic coal tar dyes and the whole list of pharmaceuticals from palmetto and other sources, hitherto unsuspected as being fundamental to organic chemical products. These statements, by implication, and by omitting mention of the extensive plants erected and put into operation by the old, established chemical companies in 1915, tended to create the public belief that these companies were doing nothing to supply the American market.

Some of the most important products which were widely heralded as having been produced for the first time in America in 1915, were manufactured by these companies 15 to 30 years ago. Benzol and its homologues have been regular American products, with shipment in carload lots or tank cars, and with occasional exportation to Europe, since 1900. Salicylic acid was manufactured at Jersey City by Zinsser & Company from 1880 until 1897, when foreign competition closed the plant.

SYNTHETIC CARBOLIC ACID

Synthetic carbolie acid was manufactured by the Semet-Solvay Company from benzol at Syracuse in 1900 and the following years, in quantities up to 2500 lbs. daily. This carbolie acid was synthesized into trinitrophenol, commonly known as picric acid, which was bought by the United States Government for use in national defense. The United States had several well equipped plants, prior to 1885, for manufacturing the principal coal dyes of that day. The industry grew, and produced an increasing number of synthetics, from which all those survive which could surmount the natural and artificial barriers in the road to a complete American coal products industry. The principal ones of these manufacturers have continued without interruption, and constitute the main body of our present organic chemical industry.

The failure to give credit in the daily press for the large amount of capital invested, and for the extensive work accomplished during the past year, is not fair to these American companies which built up our great American chemical industry during the past 30 years, and who are now the prime movers in expanding our American coal products industry to meet the new conditions.

The Benzol Products Company is an example of this growth. Organized in 1910 by men long associated with the acid, alkali and coal products industry, it began the manufacture of aniline and aniline salt at Frankford, Pa., in the aniline plant operated several years before by the late Dr. Jayne. Although the company's output of aniline in 1910 was but a small percentage of the American consumption, the English and German producers immediately dropped the price from 10c or 11c per lb., where they had held it for several years, to 9c or 8c per lb.

Most of the American consumers of aniline refused

to buy this American aniline at the fair price of 9c to 10c at which it was offered. Instead they followed their usual custom and sacrificed the American producer by supporting the cut-rate foreign producers.

These American consumers were the very ones who rushed to Washington when the war began, and frantically implored the Department of the Interior to dig up right away, quick, through the Division of Mines, some unfailing source of supply to provide the two thousand or more synthetic coal dyes and pharmaceuticals which had required 45 years of German science and organization to develop. The trip to Washington was easy for them. They had been there repeatedly since 1880, whenever a tariff bill was under consideration, to advocate no tariff on dyes.

The Benzol Products Company received the support of a few of the most far-sighted American consumers, who realized that the permanent establishment of aniline manufacture in the United States was of far greater value than the profit for a few years on their purchase of aniline, at 2c per lb. below its former price. With their support the manufacture of American aniline was continued.

Since the war, a new plant was built at Marcus Hook, Pa., and put into operation in August, 1915, with ultimate capacity equal to the former United States consumption of aniline. Notwithstanding war conditions, which multiplied the price of its raw materials, benzol, sulphuric acid and nitric acid, the company sold its aniline at a price less than half the prevailing market price of aniline, during 1915.

This production of aniline, supplemented by that of a few other plants, has supplied the American market to a fairly comfortable extent.

The Benzol Products Company's aniline has been distributed, by preference, to those consumers who employ directly or indirectly the greatest number of people. The important fact is that in 1916 a supply of aniline equal to the former American consumption will be available at fair prices, and that this supply is not coming from mysterious nor untried sources.

BENZOL SUPPLY

Since 1900 the production of benzol has steadily increased in the United States, so that there was enough benzol at all times for the manufacture of dyes, if the industry had been established by the assistance of the federal government and by the sustained support of the American textile manufacturers. Not only were both these lacking, but the textile manufacturers persistently favored the English and German producers in preference to any American manufacturers.

Benzol supply is only one factor, and alone it is not sufficient to justify the very heavy investments required to establish an American coal products industry.

In 1915 several steel companies operating by-product coke ovens, installed benzol recovery plants, so that a heavy production of American benzol is assured. When the war ends the output from these plants will be so abundant that it may become available as motor fuel for automobiles. In this service, 1 gallon of motor benzol gives 15 per cent greater mileage than does 1 gallon of gasoline.

ACIDS AND ALKALIES THE FOUNDATION OF COAL PRODUCTS INDUSTRY

Under the abnormal conditions and inflated prices caused by the war, many small plants sprung up and have produced products derived from coal at a profit. At the end of the war these plants will fall like autumn leaves. A few will struggle on and consume their war profits in hopeless endeavor to establish permanent busi-

ness. Only those built on a firm economic basis will survive.

The manufacture of products derived from coal is not an industry by itself. It is founded upon, and is an extension of, the manufacture of mineral acids and alkalies, and was created as a means of making a wider market for those acids—sulphuric, nitric, hydrochloric, acetic, for chlorine and the like and a market for the alkali products, soda ash and caustic soda. For this reason a permanent coal products chemical industry cannot be created in America except by co-operation with, or extension of, the American acid and alkali manufacturing companies.

THE VALUE OF EXPERIENCE

In 1915, with prices ten to fifteen times normal, it was possible to manufacture some coal products with large profit in the United States. With the return to normal conditions, we must conduct our processes with keenest attention to the most scientific methods, because losses of 1 per cent or 2 per cent in the steps of manufacture mean bankruptcy.

Proof that Americans sadly lack this scientific detail was given in 1915 by the many serious accidents, fires and explosions in plants manufacturing these products, the cause of which was faulty engineering design, inexperienced superintendence, untidy plant housekeeping and careless workmen.

With unconscious humor, we have done homage to German efficiency by ascribing these accidents to the German diplomatic service.

To illustrate the necessity of attention to detail, take synthetic manufacture of carbollic acid. This process, starting from pure benzol, involves five chemical reactions and from ten to fifteen chemical operations, if all by-products be recovered. If an avoidable loss so small as 1 per cent or 2 per cent be permitted in each of these steps, the final yield of carbollic acid would be so low that the process might be a commercial failure. Yet carbollic acid is one of the most simple products to manufacture.

Many others involve more steps, or steps in which the lack of technical skill produces larger loss. For example, a certain product with a normal price of 30 cents per pound has a possible maximum yield of 100 units attainable by extreme care in manufacture. With moderate care the yield drops to 88 per cent, and with ordinary care the yield drops to 75 per cent. Expressed in dollars and cents the result per ton is:

Possible yield, 100 per cent, 2000 lb., at 30c.....	\$600.00 per ton
Usual yield, 88 per cent, 1760 lb., at 30c.....	528.00 per ton
Common yield, 75 per cent, 1500 lb., at 30c.....	450.00 per ton
Loss, at 88 per cent.....	72.00 per ton
Loss, at 75 per cent.....	150.00 per ton

NATIONALIZATION OF THE INDUSTRY

Approach to 100 per cent technical efficiency is not the only requisite for commercial success. The intricate processes yield numerous by-products. Some are acids and alkalies which must be recovered and returned for use in the process. Others are salts or coal products which must be refined and sold. For many of these no market exists in the United States.

A network of markets must be created for every one of these by-products, either in the United States, in South America, Asia or Europe, if our American coal products industry is to grow with the world and pay reasonable dividends on the investment.

It is not sufficient that American consumers acquire the habit of buying chemicals "made in the United States." Our chemical industry, to endure, must cover the world's market; indeed, its ultimate success may depend upon an American merchant marine.

The German system of nationalized industry handles this multitude of by-products with military precision, by fitting each one into the particular technical and commercial chink best suited to it, so that all by-products are marketed at or about cost. This permits the main product to be sold at a profit large enough to sustain the normal growth of the plant and to develop new products, without adding new capital, and in addition to pay 10 per cent to 25 per cent dividends.

In complete contrast it has been, and is, the policy of our federal government to forbid any such interlocking national co-operation.

NATIONAL DEFENSE

The coal-products chemical industry is vital to national defense. One source of the extraordinary military strength of Germany is her ability to manufacture ammunition, literally from the air and earth, in unlimited quantity. This ability was created by the chemical industry, which built huge works and trained an industrial army of men with the scientific knowledge and technical skill necessary to transform the nitrogen of the air, and certain ones of the coal products, into ammunition. The fundamental reason for the support which the Imperial Government gave to the coal-products industry was that Germany should develop a supply of ammunition adequate for national defense and world conquest.

While developing home resources, the German industry bought benzol, carbollic acid and other crude coal products from England, thus absorbing England's commercial and military strength. Meanwhile we were more backward than England, for we were so quick to grasp the red-hot opportunity presented by German dyes and pharmaceuticals at low prices that we did not even take the trouble to produce enough crude coal products to export.

Ammunition cannot be manufactured in sufficient quantity during the interchange of diplomatic notes prior to war; it must be manufactured and stored long in advance of hostilities. One main national defense is that great coal-products chemical plants be established and operated steadily at commercial profit during peace, so that they will be instantly available to produce unlimited ammunition during war.

In 1915 we built many ammunition plants in the United States, every one on an artificial basis; few of them can make a profit at peace prices. Unless the United States establishes a complete and profitable national coal-products industry on a basis to keep abreast with all scientific progress, our program of "National Preparedness" will descend to the plane of comic opera.

NITRIC ACID FROM THE AIR

Nitric acid from the air is one step in such scientific progress. Our supply of nitric acid comes now from nitrate of soda imported from Chili. After the war, if the importations are not obstructed, we will receive nitrates and nitrogenous products manufactured in Norway and Germany by fixation of atmospheric nitrogen. Part of these products will be for fertilizer, part for explosives.

Exhaustion of the nitrate of soda mines in Chili will ultimately make the United States wholly dependent upon this European supply, unless we manufacture our own nitrates and nitric acid from the air.

The potash situation is a parallel condition. With German potash cut off, we have no potash. Various American sources will be brought into operation, but several years must elapse before we produce all the potash we consume.

Fixation of atmospheric nitrogen as nitric acid will also require several years, even though the Federal Government give the manufacture its strongest support.

Nitric acid is the effective end of every explosive and is the first chemical reagent used in the manufacture of aniline, and thence of indigo and others of the most important coal products and dyes. Without nitric acid, our entire navy, army and coast defense becomes helpless the instant the stock of ammunition is exhausted.

Our entire investment in national preparedness will be wasted money, if it does not include the manufacture of nitric acid from the air on a scale to render us absolutely independent of foreign nitrates.

TARIFF

A reasonable tariff, if formulated upon rational lines, will be of much value in supporting our coal-products manufacture. Such a tariff would divide these products into three classes according to their degree of advancement in manufacture, and would levy duties proportionate to this degree. The classes would be, first, crude products; second, intermediates; third, dyes, pharmaceuticals and highly refined products. The duties should be: On crudes, 10 per cent ad valorem; intermediates, 20 per cent ad valorem, and dyes, 30 per cent ad valorem.

If a specific duty be included it should be at the rate of 3¾ cents per pound on the intermediate class and 7½ cents per pound upon dyes and pharmaceuticals. There should be no specific duty on crude products.

The free list should include coal tar, coal-tar pitch, creosote oil and mineral acids. Natural indigo and other natural dyes of vegetable or animal origin should be placed with synthetic dyes, in class three.

Class 1—crude products—should comprise a small list. It should be described as: all crude products of coal produced through destructive distillation of coal, or otherwise, and not refined by more than one distillation, nor refined by any process other than distillation, nor refined nor produced by synthesis; such products being crude light oils, benzol, toluol, xylol, cumol and naphthalin, crude-tar acids containing less than 80 per cent pure-tar acids, and all other products from coal not otherwise specially provided for, and not medicinal and not colors or dyes, the duty to be 10 per cent ad valorem.

The second, or intermediate class, should include all products manufactured from those of the crude products class, and all so-called intermediates, not colors nor dyes nor pharmaceuticals nor medicinal products, such products being phenol, cresol, aniline, anthracene, etc.—duty 20 per cent ad valorem and 3¾ cents per pound specific.

The third class should include all colors or dyes derived from coal, including indigo, natural and synthetic, and alizarine—dry or suspended in water—and dyes obtained from indigo or alizarine, and all products derived from coal, which are used for pharmaceutical or medicinal purposes, or other purposes—duty 30 per cent ad valorem and 7½ cents per pound specific.

Natural indigo and all dyes, pharmaceuticals and medicines, and all other products derived from natural sources of vegetable or animal origin, and which are used interchangeably with similar products derived from coal, should be included in class three.

ANTI-DUMPING CLAUSE

There should be an anti-dumping clause to prevent unfair competition instituted for the purpose of destroying American industry. A dumping clause must be drafted with utmost care and its working tactfully handled. If it be too drastic, or if handled without

good judgment, it will become worthless, or worse, because foreign countries, in retaliation, will inflict the anti-dumping penalty upon any American manufacturers who may sell their goods in those countries at lower prices than in the United States. We cannot afford to take any chances with American industry now when our export trade in manufactures is becoming better established than ever before in our commercial history.

COMPULSORY WORKING OF PATENTS

Compulsory working of patents looks attractive in theory. In practice there has been nothing in the history of the coal-products industry which could have been changed or improved by it to the slightest degree. Compulsory working of patents has been tried in England, France and Russia as recently as 1907, and proved a total failure in those countries.

As stated by the German authority, Prof. Otto N. Witt, "the success of a coal-tar-dye factory is no longer dependent upon the careful guarding of factory secrets as in the past, but upon a systematically arranged plant and the proper distribution therein of the work to be performed, and above all upon skillful commercial management, both within and without the factory."

LACK OF TECHNICAL COMMON-SCHOOL EDUCATION

Lack of technical common-school education is a further disadvantage from which we suffer. Our system of early nineteenth-century education includes no technical or trade schools, by which in Germany the entire population is perfected in twentieth-century methods for earning their living in twentieth-century industries. In consequence American labor does not give effective attention to its job, and it is extremely difficult to secure labor in the United States which will give competent attention to the delicate chemical manufacturing operations of the coal-products industry.

In summary, the essentials for creation in the United States of a complete industry in the manufacture of products derived from coal are: Co-operation of the American acid and alkali manufacturers with the coal-products industry; co-operation of the American consumers with American products through long-term contracts to assure us the American market; establishment of the industry on a peace scale big enough to make it a fundamental factor in national defense; establishment on a profitable commercial basis of the manufacture of nitric acid, by fixation of atmospheric nitrogen; nationalization, or rather internationalization, of the industry to insure a balanced world market for all by-products; development of a system of twentieth-century common-school and technical-school education, and finally maintenance of a rational tariff.

That a larger coal-products industry will be established in the United States is certain. The degree to which it attains perfection will be in proportion to the extent with which these requirements for its profitable operation are provided.

Semet-Solvay Company,
Syracuse, N. Y.

The Canadian Mining Institute will meet in annual session at Ottawa, March 1, 2 and 3, 1916. Professional and business sessions will be held on the first two days, and the annual dinner will be held on the evening of the second. The third day will be devoted to a series of excursions to points of interest, including the mint, the Victoria Museum, and the Government ore-testing laboratories. The professional sessions will be marked by several important symposiums on various subjects, among which are flotation and mining education. Prof. J. W. Bell will present the results of ore-crushing experiments at McGill University.

Presentation of Perkin Medal to L. H. Baekeland

Report of Proceedings, Presentation Speech by Dr. Chandler,
Speech of Acceptance by Dr. Baekeland

On the evening of Jan. 21, in Rumford Hall of the Chemists Club of New York, amid beautiful decorations of roses, in a lavish setting of flags, bakelite products and velox photographs, before a very large, enthusiastic and representative assemblage, the Perkin medal was formally presented to Dr. L. H. Baekeland.

Dr. WM. M. GROSVENOR, chairman of the New York section of the Society of Chemical Industry, presided. In his introductory remarks he sketched the scope and the history of the Perkin medal, which is annually awarded for most distinguished service in industrial chemistry by a joint committee of the different American chemical societies.

Dr. CHARLES F. CHANDLER, the beloved dean of chemistry in America and senior American past-president of the Society of Chemical Industry, made the formal presentation speech in his happiest mood.

Dr. L. H. BAEKELAND accepted the medal in a few words of thanks, full of deep feeling.

Two deliciously informal speeches were then made by men with whom Dr. Baekeland had been closely connected in his professional career. Mr. RICHARD A. ANTHONY who had given Dr. Baekeland his "first job" in America as a photographic chemist, expressed his delight of having finally found out the secret of velox—that washing can be overdone. He recounted various instances from later life in which he had consulted Dr. Baekeland, in different chemical projects, the advice given always turning out right.

Mr. ELON HUNTINGTON HOOKER, president of the Hooker Electrochemical Company, followed with an exceedingly clever speech, recalling the early days when the Townsend cell was being tested out on a semi-commercial scale:

In this Republic, when offering the highest laurels, we delight to trace back the connection, with humble associations, of him we honor. So it is characteristic to wish to link this occasion with the amusing, but, none the less, highly dramatic and serious incidents of Dr. Baekeland's intervention in the original testing of the Townsend Process in commercial units. Imagine, if you can, a wing of the Edison power station in an altogether disreputable section of Brooklyn. Two full-size Townsend cells, erected with necessary supply tanks, exhaust chimney, etc., producing chlorine in juxtaposition to the valuable generating units of the Edison Company. Upon these the lighting and transportation conveniences of the "city where we sleep" are dependent.

Picture further, three young men, who did not know chlorine gas from ottar of roses, or caustic from lemon ice, but of undoubted bravery, assisted by negroes whose only aim was Saturday night's pay and the hope of a possible bleaching,—picture them, guided sporadically by Townsend and Sperry, but presided over, their drooping spirits revived, and their hope of heaven determined, by the genius of Baekeland. He, you understand, had just been rescued from the depths of photographic invention, with its spirit-dulling materialistic opulence, and uplifted to the rare delights of electrolytic research—that shadowy borderland between pure science and commercialized industry where

mathematics and chemistry join hands in the great unknown.

Here our friend held forth long hours in shirt-sleeved efficiency, while his social reputation became tainted, his domestic status strained, and his short nights of peace in Yonkers, even in Harmony Park, were rent with agonized appeals for help from Brooklyn at 3 o'clock in the morning: "Cell No. 1 has broken down; the place is full of chlorine gas; we are all out in the street; the Edison boss says his \$100,000 generators are being eaten by a green substance. What shall we do?" Answer:—punctured with picturesque speech: "Start it up, of course. I will be over before breakfast."

Or again: "Cover cell No. 2 has blown off from hydrogen pressure. What would you do?" Answer:—in voice choked with sleep, or deep emotion, and clothed in pajamas: "Put on a new cover and have the darkey sit on it until I can get over in the morning."

That Brooklyn equipment had been timed with all the nicety of shrapnel. Exhaust fan and stovepipe chimney resisted the chlorine until a mere shell, and then, like the "wonderful one hoss shay," crumbled into a mass of iron dust the last day of the test. The Edison janitor shoveled us into the street and, like a true homeopath, disinfected the place from garret to cellar with drums of chloride of lime.

Mr. Hooker then spoke of Dr. Baekeland as a man. "You all know his multifarious activities; a helping hand here, a word of inspiration there, a cheery hand grasp, with wisdom dissolving away technical difficulties; speech clean, from a heart that thinks no ill of others, the standard of professional ethics carried high where all can approve, and a breadth of scientific grasp

and knowledge which illumines whatever his swift mind plays upon. We, his friends, lack the proper perspective to do him and his work justice. Time alone can furnish that."

In conclusion Mr. Hooker pointed out how Dr. Baekeland "has put his faith and his life into American institutions, until he stands, known of all men, as one of the best Americans—one whose enthusiasm, patriotism, and love of his adopted country takes us back to the Americans of an earlier day. It is thus I like best of all to think of him."

The proceedings were concluded by Dr. Baekeland's long and very interesting, instructive and suggestive formal speech of acceptance which truly fascinated his audience.

Twice during the proceedings Mrs. Baekeland's name was mentioned. First, when Dr. Grosvenor in his opening speech referred to the floral decorations "for which we have to thank one who has had very much to do with the genial success of Dr. Baekeland—Mrs. Baekeland." Again, when in his address of acceptance Dr. Baekeland spoke of his university days in Belgium, he said that one of the most fascinating discoveries he then made was the fact that his senior colleague in the chemical department had an unusually attractive daughter and that this discovery led a few years later to the most interesting and successful experiment of his life.



L. H. BAEKELAND

We herewith publish in full the two formal addresses of Dr. Chandler and Dr. Baekeland:

Presentation Address

BY PROF. C. F. CHANDLER

Mr. Chairman and Brother Chemists:—It is my privilege and very pleasant duty, as Senior Past-President of the Society of Chemical Industry, residing in this country, to present to Leo Hendrik Baekeland, B.S. and D.Sc., the tenth impression of the Perkin Medal, in recognition of his most original and valuable work in applied chemistry.

Dr. Baekeland was born in 1863 at the old Flemish city of Ghent, where he received his early education. He passed through the elementary schools, the Athenaeum, a Government High School, where he prepared for the University, and the Ghent Municipal Technical School, which resembles our Cooper Institute.

In 1880 he entered the University, where he studied various natural sciences, specializing in chemistry. Although the youngest student in his class, seventeen on entering, he promptly won his degree of B.S. and later, when 21 years old, the youngest graduate, he received his degree of Doctor of Science, passing his examinations with the highest honors.

Dr. Baekeland must have been as industrious while a student, as he has been since he graduated, for from the age of seventeen he supported himself entirely by tutoring and as lecture assistant.

Later he was appointed assistant professor, and in 1889 associate professor at the University of Ghent.

In the meantime, in 1887, he had been appointed professor of chemistry and physics at the Government Normal School, then existing in the city of Bruges.

In a competition among the alumni, who had graduated from the four Belgian universities during a preceding period of three years, he was awarded the first prize in chemistry, by a jury of the senior professors of chemistry of the four universities: Theodore Swarts and W. Spring for the Government Universities of Ghent and Liege; P. De Wilde and Louis Henry for the Universities of Brussels and Louvain. The president of the jury was Jean-Servais Stas, best known by his classical researches on the atomic weights.

This prize, besides a gold medal and other rewards, entitled him to a traveling scholarship, by which he was enabled to visit some of the universities in England, Germany and Scotland, and to make a trip to the United States in 1889.

I have given you these details of Dr. Baekeland's early life, because I believe few, if any, of you were familiar with them; because they are most creditable to him, and show his personal character, and because I knew he would not disclose them himself.

Before leaving Ghent, he had become deeply interested in photography. Since the early eighties Ghent had become a center of the new industry of dry-plate manufacturing, started there by Dr. Van Monckhoven.

Dr. Baekeland was an enthusiastic amateur photographer, and had followed every step of the new processes, with the result that he acquired some reputation in this new branch of chemical industry.

On his arrival in New York, he became acquainted with Richard A. Anthony of E. and H. T. Anthony & Co., with whom I had been associated for some time as editor of their photographic bulletin. Richard Anthony brought us together, and I think it was a case of love at first sight, for we have been the very best of friends ever since.

The Anthony firm, which later joined the Scoville Company in establishing the Ansco Company, had engaged in the manufacture of photographic films and bromide paper, and they offered Dr. Baekeland an ex-

cellent position as chemist in their factory, an offer which he promptly accepted, deciding to remain in the United States.

The Minister of Education of Belgium, in accepting his resignation, paid him the unusual compliment of authorizing him to retain the honorary title of "Associate Professor at the University of Ghent."

After two years, he left the Anthony firm and established himself as a consulting research chemist, and devoted himself to developing several chemical processes which he had devised.

In 1893, in partnership with Mr. Leonard Jacobi, he founded in Yonkers, the Nepera Chemical Company, where he started very modestly the manufacture of various kinds of photographic papers. One of these papers, which was called "Velox," has since earned a great reputation as a photo printing paper.

Dr. Baekeland had worked to perfect this paper as far back as 1883, while he was still a student in Ghent, but its importance as a possible subject for a commercial enterprise did not become apparent to him till much later.

Silver-chloride emulsions had been proposed and described in 1891 by Eder and Pizzighelli, but their process was carried out along the same general lines as silver-bromide emulsions, namely, precipitation and ripening, followed by washing to remove the soluble salts resulting from the reaction.

Baekeland had found that as far as chloride of silver emulsion is concerned, the last two operations, although they increased the sensitiveness of the emulsion, had a disastrous influence on the tone and general gradation of the image, specially in the shadows.

He had discovered that in order to keep these desirable qualities it was necessary to produce chloride of silver in a special colloidal condition, which is easily disturbed by any after treatment of the emulsion, as for instance, "ripening" or "washing."

By committing an act of "photographic heresy" in omitting the washing entirely, Baekeland found he could make a variety of colloidal silver-chloride which was relatively insensitive to the yellow rays of the spectrum, and therefore could be manipulated by candle or gas light, if not brought too near.

This made the paper incomparably inferior to bromide paper, or ordinary chloride of silver paper, as far as speed is concerned.

But Baekeland realized the important fact that by exposing quite close to the artificial light, and developing the image at a safe distance (a few feet) the apparent defect could be turned to a great practical advantage.

But the process had to be studied in all its endless details of manufacture before it could be carried out on a large scale, so that it could be standardized for use by the photographic public, which was no easy task.

The paper was put out in the trade under the name of "Velox," and met with very scant favor at first; in fact, it took years of education and hard work before the value of the process was fully recognized.

Then as soon as the first indications of success were apparent, several competitors started in the same field.

But after the value of the process was clearly recognized, it gained rapidly in popularity, and in 1899 the Eastman Kodak Company offered to buy out the entire business enterprise on very liberal terms, which were promptly accepted.

This relieved Dr. Baekeland from all further commercial worries, and placed him in a position in which he was free to live the life he had always ardently desired; in which he would be able to devote his time and energy to study and research, free from school, university and business cares.

Dr. Baekeland next turned his attention to electrochemistry. It was a new branch of chemical industry scarcely known in his early student days. Its field was limited then to the electro-deposition of a few metals from aqueous solutions, such as copper, nickel, silver and gold.

He was very much impressed by the wonderful expansion of the applications of electricity for chemical purposes in recent years, especially in the United States.

Charles M. Hall, a Perkin medalist, had brought out his beautiful and simple process for extracting aluminum from alumina, in 1886, and had given a practically new metal to the world to replace copper, tin and zinc in many arts.

Hamilton Y. Castner, a Columbia boy, had invented, in 1890, his simple process for making sodium a commercial metal, and simplifying the preparation of some of its most valuable compounds, as cyanide and peroxide; and in 1892 his ingenious process for making pure caustic soda and chlorine from salt.

Edward Goodrich Acheson, a Perkin medalist, in 1892, had discovered carborundum, and devised a simple process for producing it in unlimited quantities, and in 1895 had devised his process for the manufacture of artificial graphite, which he followed later, in 1906, with the invention of that remarkable and useful substance, "deflocculated graphite."

Thomas L. Willson had, in 1899, devised a process for producing in unlimited quantities crystalline calcium carbide, which by the action of water creates acetylene gas, and by the action of nitrogen from the atmosphere, produces the new and most valuable atmospheric fertilizer, "calcium cyanamide."

There are two facts which make me linger here with pleasure: every one of these inventions was made by an American chemist, and every one of them resulted in the establishing at Niagara Falls one or more large works, where the inventions are utilized by the use of electricity developed by the waters of Niagara.

These industries are financed, and most successfully worked by the Aluminum Company of America (Hall's aluminum); the Niagara Electro-chemical Company (Castner's sodium and cyanides); the Castner Electrolytic Alkali Company (Castner's caustic soda and chlorine); the Carborundum Company (Acheson's carborundum); the International Acheson Graphite Company (Acheson's graphite and deflocculated graphite), and the Union Carbide Company (Willson's calcium carbide).

Who can question the ability of American chemists to make original researches and devise new and useful processes? These are not all, by any means; they are merely examples which I have selected because I am most familiar with them.

Dr. Baekeland was very much impressed by these developments, and decided to enter the electrochemical field. So he spent a winter at the Technological Institute at Charlottenburg, near Berlin, in the electrochemical laboratory, to freshen up his knowledge of the subject.

On his return to America he equipped a modest private laboratory on his grounds at Yonkers, and provided it with a few electrochemical appliances for further study.

His work drifted in many other directions, but about that time Mr. Clinton P. Townsend had just invented his now famous electrolytic cell, for producing caustic soda and chlorine from salt. Baekeland was requested by Mr. Elon H. Hooker to take the direction of the work preliminary to the industrial development of this invention. This he did in company with the inventor and several other skilled experts.

The work finally resulted in the formation of the

Hooker Electrochemical Company, and the erection at Niagara Falls of one of the largest and best equipped electrochemical plants in the world, with which he is still connected in an advisory capacity. In this connection he took out his first two patents, "apparatus for regenerating electrolytes," and "an electrolytic diaphragm and method of making same."

BAKELITE

Dr. Baekeland's crowning work is the solving of the mysteries involved in the action of formaldehyde upon phenols, and giving to the world the new material "bakelite."

Bakelite is a so-called condensation product of phenol—or carboic acid—and formaldehyde. Instead of phenol, its homologues, cresols or other phenolic bodies can be used. Instead of formaldehyde, other substances which have the same functions may be utilized, as, for instance, methylal, paraform and hexamethylenetetramine.

It should be well understood that formaldehyde in reacting upon phenol does not necessarily give bakelite. Quite to the contrary, it is only under very special conditions, now well established by the published research work of Baekeland, that this substance can be obtained.

In fact, when formaldehyde is let to react on phenol under ordinary conditions, almost anything may happen but the formation of bakelite.

There are very few examples where the same two substances, reacting upon each other, can give such a variety of products. For instance, a nicely crystalline substance, called saligenin, or oxybenzyl-alcohol, found in the willow-tree (*Salix*), may be the result. This substance has been used in medicine, and is known also as diathesisin.

In other cases, a resinous material is formed, but it has no specially new properties and is very similar to cheap, natural resins. For instance, it can be melted and dissolved rapidly just like any other natural resin, and neither its hardness nor other general properties give it any special claim above the natural resins.

This is the substance which has been called novolak, and which has been prepared by Blumer and others; it has never found any serious applications as such, although at one time it was expected that it would be useful as a shellac substitute, when the price of shellac was unusually high.

It is generally known that as far back as 1872 Adolf Bayer and his pupils (Ber., 5, 1095; 19, 3004; 25, 3477; 27, 2411) showed that it was possible to obtain condensation products of *aldehydes* and *phenols*. These experiments, at this time, were not conducted with formaldehyde, because formaldehyde, as such, was not obtainable, so the reactions were mostly conducted either with the methylen representatives of formaldehyde or with the then available acetaldehyde.

The substances studied at that time varied considerably in character and embraced more particularly certain crystalline, well defined products. Now and then some uncrystallizable substances were obtained, but no special attention was paid to them, nor had they much in common with the present product, except that they had a resinous appearance.

About 1891, formaldehyde was put on the market as an article of commerce, and Kleeberg (*Annalen*, 263, page 283, 1891) tried to repeat some of the work of Bayer by using formaldehyde, in presence of strong hydrochloric acid. He thus obtained a worthless, irregular mass, which he attempted to purify by the usual methods and bring to a constant composition, but he did not succeed, so he dismissed the whole subject and continued his studies of phenolic condensation products along other lines which enabled him to prepare well

defined crystalline substances which have nothing to do with the present subject, except the origin of the raw materials.

Others, like Smith, Luft and Story, took up the same subject, using formaldehyde, endeavoring to master this reaction either by the presence of solvents, which were partially eliminated afterward, or by the introduction of foreign substances like camphor. But none of these processes developed into anything on which an industrial enterprise could be founded with any chance of success.

In the meantime, Blumer and De Laire had described methods by which formaldehyde and phenol could be made to produce, with certainty, special resinous substances which were entirely analogous to the natural resins, like shellac, copal, etc., of which they had practically all the general properties; that is to say, they were fusible, they could be melted, they could be dissolved in suitable solvents. These processes were calculated carefully to avoid the formation of anything but these fusible and soluble products, on which they built great hopes as possible substitutes for shellac.

If the methods of preparation described by these inventors are not carefully followed, then it happens frequently that disturbing side products are produced. The latter, instead of being easily fusible and soluble, are irregular masses of the Kleeberg type containing variable amounts of infusible and insoluble substances which are of no value for further purposes, because you cannot do anything with them after they are once formed. These are exactly the substances which Kleeberg had rejected on account of their negative properties.

This was the state of the art until Baekeland made the disclosure of his own work. He was particularly attracted by the failure of Kleeberg and hoped to find a suitable solvent for his worthless product. It occurred to him that if he could find a solvent for this material he would be able to make a varnish superior to all existing varnishes. The difficulty was to find the solvent.

His assistant, Mr. Nathaniel Thurlow, felt very skeptical about it and pointed to the unsuccessful attempts of others, after trying most of the available solvents. The fusible, soluble resins of the Blumer and De Laire type seemed considerably more attractive.

But Baekeland took the point of view that their qualities were not better than those of the natural resins. In fact, in practical tests on a large scale, he had found that in many respects their qualities were inferior to those of shellac, which, furthermore, could be purchased at a more advantageous price than the cost of production of these synthetic resins.

So he concluded to purchase or prepare further solvents of every kind so as to determine whether he could not do something with the substance of Kleeberg, and finally, after many renewed attempts, he had to give it up as a hopeless task.

Then he changed his tactics. He reasoned that if nothing could be done with the substance after it was once produced in a flask or any other vessel, he should attempt to carry out the reaction so as to generate the substance right on the spot where he wanted it. For example, he thought that if he could make the synthesis inside of the fibres of wood by injecting first the two reacting raw materials, and then start the reaction, he might be able to incrust the fibres of the wood with an unusually hard and inert substance, and give to the wood new properties.

This was easier said than done. He encountered endless difficulties. Certain classes of wood, specially the higher grades, instead of becoming harder, became softer. He also noticed that chemical reactions in these

capillary conditions proceed in a very different way than in a flask or other container, for the reason that the chemical dynamics in capillary spaces are considerably disturbed, so that the reaction which may terminate rapidly and completely in a wide vessel, will be considerably hampered when the mobility of the reacting molecules is disturbed by capillary conditions.

He also perceived that, just on this account, the carbo-lic acid, before it had time to react upon the formaldehyde, had every opportunity for destroying the fibre. He concluded that in order to have any success, he should either be able to speed up the reaction by some special means, or he should find a way whereby he could partially start the reaction outside of the fibre of the wood in a flask, and finish it afterward within the tissue of the wood, after injection.

This led him to a long systematic investigation, when he tried to study all the different factors of the reaction. When he was through with this line of research he had established practically all important facts on which is based the foundation of the present industrial processes of bakelite.

He found that under certain conditions he could dissect the reaction in different succeeding steps, where one of the first steps was the production of a certain intermediary substance which, although it had the general appearance of a resin on account of its brittleness, its solubility and its fusibility, differed radically from the natural resins by the fact that as soon as he heated it at a certain temperature above its melting point, it changed into an entirely different body incomparably harder and stronger than the original resinous material, and which, furthermore, looked like natural amber although it was much stronger than amber, and had another advantage over amber or similar resins, in the fact that it did no longer melt if heated, and that it was insoluble in all known solvents.

He also established the fact that in the different reactions which engendered this substance, there is one phase where polymerization occurs and that this phase is accompanied by self-heating, which brings about a considerable rise of the temperature of the mass, so that whenever any attempt is made to hasten this part of the process which produces hardening, the self-heating becomes so exaggerated that gaseous products are evolved, which blow up the mass and cause porosity, which makes it worthless. In order to offset this, he introduced, besides other means, the use of a very strong counter-pressure during the period of polymerization.

He discovered also the important fact that the presence of ammonia, or another base, in suitable proportions, will surely make the reaction go the right way toward the production of the infusible product, while with the presence of an acid, the formation of permanently fusible resins will be favored in case the amounts of carbo-lic acid are preponderant; that furthermore, the use of a suitable base in proper quantities gives an easy means of controlling the reaction at whatever phase is desirable. From then on, it became possible for him to avail himself of practical means for preparing, as a starting point, an initial condensation product which was still fusible and plastic, and do with it whatever he pleased while it was still in that initial condition. For instance, he could mold or form it or dissolve it, and then afterward, under the action of heat, polymerize and harden it to the final condition of maximum hardness and strength, where it is no longer fusible or soluble after it had acquired its permanent shape.

The initial bakelite is designated usually as bakelite A; before it is polymerized, it dissolves and melts to a liquid; but this liquid has the strange property of

"freezing" when sufficiently heated and then afterward can never again melt or dissolve; it has been "polymerized" into bakelite C.

It should be pointed out here that ammonia, in conjunction with formaldehyde, gives a chemical which is called hexamethylenetetramine, and that the action of ammonia in presence of formaldehyde in this process is entirely similar to that of the use of hexamethylenetetramine.

It was found also by him that the mechanical properties of these infusible condensation products were enormously improved by the introduction of fibrous substances, as for instance, wood fibre or asbestos. All pulverulent fillers which are successfully used in conjunction with other plastics, instead of improving bakelite, make it worse. This is due probably to the fact that bakelite, although it has an unusually high tensile strength, has a relatively low degree of elasticity which makes it sensitive to impact and shock. The introduction of fibrous materials into bakelite makes it enormously more resistant to shock than the pure article.

Many other facts were established by his work. For instance, it was demonstrated that among the homologues of phenol, it was not indifferent what kind of homologues is used. It so happens that ortho-cresol tends towards the formation of fusible products of low strength. Para-cresol also gives condensation products of very inferior qualities, while meta-cresol, or mixtures of meta-cresol and para-cresol, give the best product. This enables the use of some of the more available cresols, instead of expensive phenol.

He not only pointed out unmistakable methods for producing every time, at will, either a fusible or an infusible resin, but he gave the explanation why in one case one substance and in another case, a different one was obtained, when starting from the same raw materials. He established the theoretical relations and parentage of those different substances, all derived from the same raw materials and yet so different in their properties and technical uses. In this way, he established the relation between the crystalline product saligenin (oxybenzylalcohol) contained in the willow tree and how it is possible ultimately to convert it, at will, either into the fusible resin of the Blumer type, or into bakelite, by submitting it to further chemical reactions.

To sum up: Before he had published the results of his work, there existed not a single industry, nor a single application of any importance based on these condensation products. Since he has published his patents and read his papers before the American Chemical Society, there have been started here and in Europe numerous factories where these processes are used for the most varied purposes, ranging from the manufacture of a billiard ball to that of a wireless telegraphic apparatus; from the manufacture of a self-starter for automobiles to that of transparent fountain pens, this range of varieties embracing such articles as switchboards for battleships, moldings for kodaks, phonograph records, casings for instruments of precision, armatures and commutators for dynamos and motors, telephone receivers, railroad signals, grinding wheels, umbrella handles, buttons, cigar holders and pipe stems, articles of ornament, etc.

The General Bakelite Company has a very complete plant at Perth Amboy, where the raw materials are made; there are a large number of licensees in the United States; bakelite plants in Germany, France and England; and several factories in Europe where bakelite goods are manufactured under license, for example, two bakelite button factories in Germany and one in Russia.

It is absolutely impossible to tell the story of "bakelite" with any completeness in the time allotted to me, and I must refer you to Dr. Baekeland's articles and patents, where you will find everything fully set forth.

I have prepared a complete list* of the United States patents, arranged in the order in which they were applied for, as that order will enable you to follow chronologically this stupendous investigation.

There are many additional patents which have been allowed but not yet published, and many more which are now before the Patent Office.

It was at first thought by some persons that some of the early investigators, beginning with Adolf Bayer, whose names I have already mentioned, must have anticipated Dr. Baekeland in his discoveries and inventions. This is not the case; Dr. Baekeland's inventions, as described in his patents, are not anticipated.

The subject was most thoroughly tried out in the United States District Court, Eastern Division of New York, before Judge Chatfield, who rendered his decision in Dr. Baekeland's favor, in a most elaborate and lucid opinion, covering twenty pages of The Federal Reporter. His Honor clearly pointed out step by step the radical differences between the work of Baekeland and each one of the prior writers and patentees.

In closing I will call attention to the distinctions which Dr. Baekeland has had showered upon him, in recognition of his scientific standing and achievements in the domain of industrial chemistry: President Chemists' Club, 1904; vice-president Society Chemical Industry, 1905; chairman N. Y. Section American Chemical Society, 1908; president American Electrochemical Society, 1909; president American Institute Chemical Engineers, 1912; president Inventors' Guild, 1914. Official U. S. delegate to International Congress of Chemistry, London 1909; president Section of Plastics, International Congress of Chemistry, New York, 1912; first Chandler Lectureship, School of Mines, 1914; member Naval Consulting Board of United States, 1915. Nichols Medal, 1909; John Scott Medal, 1910; Willard Gibbs Medal, 1913; Chandler Medal, Columbia University, Fiftieth Anniversary School of Mines, 1914.

Leo Hendrik Baekeland, Doctor of Science, my dear friend: It gives me the greatest pleasure, as the representative of the affiliated chemical and electrochemical societies, to place in your hands this beautiful Perkin Medal, as a token of the appreciation and affection of your fellow chemists.

* * *

Address of Acceptance of Perkin Medal

BY DR. L. H. BAEKELAND

Mr. Chairman, Ladies and Gentlemen:—In accepting the great honor you are willing to bestow upon me, I realize at the same time how many of my fellow chemists have achieved much better work than anything I ever attempted. On this account, my feeling of gratitude toward you changes entirely into a sentiment of profound humility and arouses in me the ardent desire of endeavoring to do better in the future. Should I not live up to this resolution, then every time I shall look upon this medal, it will appear to me as a symbol of reproach instead of a token of merit.

And now, what shall I say further on this occasion? So much has already been told about me this evening that, if I could drop the whole subject right at this

*Dr. Baekeland's U. S. patents are \$44,314, 1906-7; \$55,221, 1906-7; \$43,671, 1907-10; \$42,699, 1907-9; \$42,852, 1907-9; \$54,666, 1907-10; \$42,809, 1907-9; \$42,808, 1907-9; \$1,057,319, 1907-13; \$42,700, 1907-9; \$39,966, 1909-9; \$1,054,265, 1909-13; \$41,605, 1909-9; \$1,019,408, 1909-12; \$1,160,362, 1909-15; \$1,160,365, 1909-15; \$1,038,475, 1909-12; \$1,246,045, 1909-15; \$67,137, 1909-10; \$1,057,211, 1907-13. The patents are given in the order of their application, the first date following the patent number is the year of application and the second is the year of issue.

point and go quietly home, I should feel intensely glad and relieved.

But the Perkin Medal Committee urges me to take this opportunity for explaining some of my experience as far as it relates to the handling of problems connected with new chemical enterprises.

Therefore, I can spare you a repetition of technical details about my work, which you have heard abundantly on other occasions, and which are now available in the chemical literature. I shall thus try to make this occasion serve a better purpose by presenting my point of view in relation to the chemical development of this country, and I hope that by the time I am through, I may have convinced some of my younger fellow-chemists that a reasonable measure of success in their chosen career is not such a difficult matter after all.

PRACTICAL LIFE AS A COMPLEMENT TO UNIVERSITY EDUCATION

Reference has been made by Professor Chandler to my early training. I feel very grateful for the excellent opportunities of education I had at the University of Ghent. I should state, however, that my real intense education only began after I had left the university, as soon as I became confronted with the big problems and responsibilities of practical life; this education I received mainly in the United States, where for twenty-seven years I was thrown in contact with so many varied subjects. I hope to remain until I die, a post-graduate student at that greater school of practical life, which has no fixed curriculum and where no academic degrees are conferred, but where wrong petty theories are best cured by hard knocks. There was a time in my life when, as a young teacher of chemistry, I was just as cock-sure as some of my older colleagues that everything was as simple as it appears in the textbooks. This lasted until I tried to make bromide of silver for commercial purposes in the preparation of photographic emulsions. Stas had already published the fact that there were three or four different varieties of bromide of silver, all of exactly the same chemical composition, yet differing in their physical properties. By the time I got fully engaged in the manufacture of silver-salt products for photographic purposes, I had come to the conclusion that instead of three or four varieties of bromide of silver, there existed perhaps a hundred varieties, but that of those hundred varieties, there was only one which might probably keep me from the poorhouse and assure me success as a manufacturer. And yet, until then, that unexciting chemical reaction which produces bromide of silver and which in our textbooks is expressed by such a simple chemical equation, always had appeared to me as hardly worth while of further investigation. By and by, I began to look at chemical phenomena from quite a different standpoint, and I well remember the day when I reasoned to myself as follows:

"Here is one of the very simplest of all chemical reactions, so simple that any chemist hardly wastes any time over it, and yet it involves phenomena so intricate, so varied in scope and effect, that we have not yet found the proper means to fathom them. Here is bromide of silver, freshly precipitated in the dark; it has the property of not darkening if brought in contact with a reducing agent—a developer—and yet the mere action of light, even for only an infinitesimal fraction of a second, brings about such a profound alteration in its constitution that henceforth it will blacken and set silver free if treated with a reducing agent, and thus produce a photographic image. Furthermore, this bromide of silver, before and after it has seen the light, is exactly the same, as far as we can decide by chemical

analysis or any of our other clumsy means of observation. Suppose now that the human race were not provided with the sense of eyesight—just as we probably are missing several other senses—we would forever remain unaware of that peculiar effect of light on silver bromide or on chemical reactions in general."

This gave me one of my first warnings not to accept any chemical explanation in too simple terms, and engendered in me the evergrowing belief that the very plainest chemical reactions are incomparably more complicated than our hasty generalizations in text-books lead us to believe.

It thus became my good luck that my early struggles with photographic problems cured me of too much confidence in easy explanations of chemical phenomena and made me lose somewhat that youthful overabundant faith in class-room theories. I suppose my experience is very similar to that of many an industrial chemist who has had to learn by sheer experience, that after he may think he knows everything on a certain subject, he is constantly confronted with endless matters of detail which at first seemed so trifling, alongside the broad lines of the subject, as to be unworthy of the attention of the theoretical chemist. And yet it is these details which frequently determine whether the practical solution of a problem is possible or not—whether the ruin or success of a chemical enterprise is in sight.

TOO MANY IRONS IN THE FIRE

Nor was it all plain sailing in my early days here in this country. Like so many others, I committed the mistake of scattering my attention on too many subjects at the same time. After I left the Anthony firm, I tried to work out, without sufficient financial means, several half-baked inventions, the development of each of which would have required a small fortune. Fortunately for me, I was taken out of this muddle and shaken to my senses by a very severe illness which nailed me to bed for several months. While I was hovering 'twixt life and death, with all my cash gone and the uncomfortable sentiment of rapidly increasing debts, I had abundant time for sober reflection. It then dawned upon me that instead of keeping too many irons in the fire, I should concentrate my attention upon one single thing which would give me the best chance for the quickest possible results.

Among many other matters, I had an electrolytic process for extracting tin, a safety explosive, and a new photographic paper. The tin process had lost all its charms since the swampy meadows of New Jersey, where I was carrying out my experiments, had brought me almost within close acquaintance of the undertaker. Nor did the manufacture of explosives appeal much to me after I had been for so many months in the hands of surgeons and physicians; so I turned to my old love, photography, ready to manufacture some new kinds of photographic paper.

THE HISTORY OF VELOX

I was lucky enough to make the acquaintance of Mr. Leonard Jacobi, of San Francisco, who was willing to risk some of his cash in my venture. He knew nothing of chemistry, nor of any technical matters, but he was a generous-minded, cheerful and very industrious man, who furthermore honored me with his implicit confidence. Although much of an idealist, he was in business matters very sober-headed and very careful and conscientious towards all the immediate problems before him, and I owe it to the excellent example of his common sense that I learned some of the practical rules of business life which afterwards came into good purpose in my future career.

Do not imagine that from the beginning of this enterprise everything went smoothly. Quite to the contrary. As luck would have it, we started this venture just at the very worst time, in 1893, during the famous business panic, when so many of the industries of the United States went under. In this instance, our salvation was that we had started on a modest scale and that whatever disadvantageous conditions we encountered, or whatever mistakes were committed, we could straighten up matters without too fatal a loss of capital.

We had more than our share of the usual technical troubles which accompany the starting of any new enterprise. It was found, for instance, that while we could make excellent paper in temperate weather, it became practically a hopeless task to do so in the hot summer days. Our sales were small and when we had any sales we were confronted with the problems of the climate and then our manufacturing methods were more or less like a gamble. This caused us considerable losses. The remedy seemed easy enough, so we tried to rectify the conditions of temperature by artificial cooling, as others had done. But this had not the required effect and new disappointments confronted us.

After awhile special scientific investigation disclosed the fact that the troubles were not due so much to the factor of temperature as the moisture in the air. This led us to install a refrigerating system over which the air could be drawn first so as to extract its moisture by precipitating it as ice, after which the dried air could be sent over heated pipes so as to raise its temperature to the proper degree before it entered in the paper-coating machine. At that time this seemed a rather paradoxical method of operating, but to-day it has been adopted by several large manufacturers of photographic papers and films. It was only many years later that I heard of the Gayley process for blast furnaces where a similar method is used for insuring the steady dryness of the air in the smelting of iron.

Manufacturers in Europe, where the amount of moisture in the air does not vary to such an extraordinary extent between seasons, have scarcely any conception of what difficult manufacturing problems are encountered here in the United States where in winter the air is so dry as to cause electric sparks and abundant static electricity by friction, while in the summer months the air is often so saturated with moisture that any objects or machinery condense humidity on their surfaces at temperatures as high as 76 deg. F. But I believe that it is just on this account that in some industries American manufacturers have been compelled to solve with more thoroughness and with more effective means, the greater difficulties they encounter here in the varying climatic conditions; this also is the reason why some of our industries have reached a higher degree of development and perfection than the corresponding European enterprises. The humidity in the air during our hot summer season, aside from the manufacturing problems, is very hard on photographic prints. Photographs made with inferior processes may give prints which last many years if kept in Europe, but it frequently happens that the same prints deteriorate here in a few weeks in summer time.

In the early nineties and following years, this country was using more and more photographic printing methods which consisted of the so-called combined-bath processes, and by which toning and fixing of the image was produced at the same time.

At that time, practically all manufacturers of new sensitized paper advocated this rather easy process. Few, if any, hesitated to promise permanency of these prints, and this on the strength that such prints had been preserved successfully in Europe. A rather simple

test gave me a method of distinguishing which kind of photographic prints were most likely to fade. This test consisted in cutting a photograph in two and exposing one-half in a jar to the fumes of ammonium-hydrosulphide. This treatment, in a few hours, showed the same amount of fading as would have been produced under ordinary conditions after months or years.

Upon the result of these experiments I had based the manufacture of several sensitized papers, which I could unhesitatingly recommend as giving permanent prints. One of these papers we called *Velox*, on account of the speed with which the prints could be made independently of weather conditions. In this process prints are exposed for a short time to artificial light and developed by the same light. I was firmly convinced that this process had a great future. Unfortunately, the public did not think so at all. In fact, it was very disappointing to notice how every photographer, amateur or professional, was wedded to the older processes and wanted to have nothing to do with the method about which I felt so enthusiastic.

To make matters worse, my very best friends did not hesitate to tell me that there was no chance whatsoever for this new method of printing, because they thought that it was so much simpler and easier to print in the sun, to which everybody was accustomed. I never was more impressed with the fact of how routine holds sway over this world; but I was rather stubborn in my point of view. I kept on trying to convince others how much simpler it is to be independent of sunshine. I shall never forget the endless correspondence I had with many people all over the country. I remember too well the kind of letters I used to receive and of which the following are some examples:

"I have tried every photographic paper in existence and I have been more or less successful with all of them until I tried yours, but it is hopelessly no good. You cannot blame my insuccess on faulty manipulation, because I am professor of chemistry at ——— College."

Or another: "I am a professional photographer of twenty-five years' experience. Your paper is the greatest photographic swindle of the age. You claim your method of printing is several hundred times faster than albumen paper, and here I have kept a print in the printing frame for several hours in the sun and I can hardly see a faint image."

It was only later on that I realized that most of those people *knew too much* about photography and, on this account, never gave themselves the trouble of even glancing at the printed directions which were sent to them; they were, like so many other people, past the age where they are willing to learn anything new.

Finally, our success came from the most unexpected quarters. A new generation of modestly beginning amateur photographers came up and began to give themselves the trouble of reading and following our printed directions. To the disgust of their more experienced friends, "who know it all," they began to show them excellent prints made on the new paper, better in several respects than experienced men in the profession had been able to produce with older processes. Nevertheless, it took considerable time before so many converts had taken up the new process that the grumblers and fault-finders were finally in the minority; it required four years of strenuous introduction before the business began to show some slight profit, notwithstanding the fact that all unnecessary expenses were carefully avoided. Two years more and the business enterprise began to prosper rapidly and then I was offered good cash for my interest in the business by the Eastman Kodak Company and I retired entirely from this field.

I should mention right here that if I had tried to sell

my processes at the beginning before they had been developed into a commercial paying enterprise, I could hardly have expected anything, because at that state my inventions would have been of little or no value beyond a mere gamble. It required the careful nursing of a business enterprise, and it was indispensable to establish firmly the process on a practical commercial scale before we were in a position to dictate our own price; even at that rate, the buyers took less risk than if they had obtained the process as a gift, before it had been worked out for several years and during several seasons. If I go into all these details it is merely as a hint to some of my friends who are apt to build castles in the air on processes which are not yet beyond their laboratory stage, and who are not willing to incur all the hard work and risk connected with their full development, and yet expect to obtain a large sum of money for their mere patent rights.

UNCERTAINTIES OF CHEMICAL PATENTS

Professor Chandler has already explained to you the underlying principles of the Velox process. I should mention that velox was never patented, except that its name is a trademark. At that time I was already aware how difficult and expensive it is to carry on patent litigation and I realized too well that we could neither afford the money nor the time connected with patent fights. So I preferred to take some chances and to keep the process secret long enough to permit us to build up a solid business by the time our competitors would have been able to devise the same methods.

Although I have had to change somewhat my views on the subject of patents, I still believe that the man who takes out a patent for chemical processes and does not have at his disposal abundant means to defend his patent-rights before the courts, is at a considerable disadvantage against unscrupulous infringers. Chemical process patents which can be followed out in secrecy can be too easily infringed with impunity because it is too difficult and expensive to establish these infringements before our courts of law.

"Product patents" for chemical substances protect somewhat better; but even there, litigation is considerably more difficult and intricate than for purely mechanical patents which are easier to understand by intelligent judges even if they have no scientific training; this important point of difference has too often been lost sight of in any proposed changes of our patent laws.

But whether you patent a chemical process or not, it appears to me of the highest importance to try it as soon as possible on a small commercial scale and thus test its essential practical details before risking too large a commercial enterprise on it.

ELECTROLYTIC SODA

I was fully imbued with these facts when, about twelve years ago, I was entrusted by my friend, Elon Huntington Hooker, with the examination of the Townsend cell. The inventor of this cell, Clinton Paul Townsend, one of the most clear-minded and careful men I have ever known, had already studied the details of his invention with a thoroughness which is rather uncommon; he furthermore, in its construction, had the benefit of the engineering experience of Elmer A. Sperry of gyroscope fame. Together they had practically tested out in the laboratory everything which seemed of importance about the design and operation of the cell. At that time there existed much skepticism as to whether a diaphragm cell for the manufacture of caustic soda and chlorine would ever rival the mercury cell, brought to such a remarkable state of perfection by that distin-

guished American inventor, Castner, a pupil of Professor Chandler.

Here, then, was a distinct advance in the art, an invention which for its commercial use required a plant costing millions of dollars. I felt it was dangerous to take any such large risk until there was an absolute certainty about the smooth working of the cell. I reasoned that we all knew *how good* the cell was under laboratory conditions where it was supervised by unusually able and skillful men, but it was just as necessary to establish *how bad* the cell would be if put under actual factory conditions where it would be operated by average labor. To investigate this was very expensive and took considerable time.

Two full-sized model cells were built and operated under varying conditions, day and night uninterruptedly for months. This gave us all an opportunity of improving details of construction. With the additional experience thus gained, we could now make more correct estimates and specifications for a full-sized plant. But even this plant was not built in full at once, but only to the extent of the smallest section which could be operated. We had thus further opportunities for detecting weak points and introducing further improvements or simplifications.

After this period, however, there was no further risk in the construction of the full-sized plant. Moreover, the experience which had been gained by the preliminary expenditure of about \$300,000, prevented blunders which might have cost several millions; through carefully planned development like this, the Hooker Electrochemical Company has to-day become one of the leading electrochemical concerns of the world.

In as far as my name has been connected with this enterprise, I take this opportunity of disclaiming any further credit for the success of its technical development, and more especially for the Townsend cell, beyond the fact that it was my good fortune to work in collaboration with a group of unusually able men. Aside from the men already mentioned, there were Albert E. Hooker, H. Willard Hooker, Clarence W. Marsh, Jasper M. Rowland, T. B. Lyster, C. N. Lansing, George W. Stone and others, all of whom did their full share in introducing a number of improvements.

I mention this example of successful team work in opposition to other instances where similar problems were entered into recklessly and where, either through impatience or through false economy, a large-sized plant was put up at an enormous cost before all doubtful details of the process had been eliminated with the result that the irregularities in manufacturing became so overwhelming and money losses became so heavy that the enterprise failed before it was possible to overcome them.

The principle "Commit your blunders on a small scale and make your profits on a large scale," should guide everybody who enters into a new chemical enterprise, even if it taxes the patience of some men who cannot conceive that one single apparently minor detail in a chemical process may upset all the good points and lead to ruin.

SYNTHETIC RESINS AND BAKELITE

When I undertook the intricate study of synthetic resins, which led to bakelite, I did not rest until I had mastered the details of the subject as far as my laboratory methods allowed me to do so. Then immediately afterwards I installed a small working unit where I could prepare the material in ton lots under various conditions, so that it could be tested right and left for practical purposes. Experience has taught me that many inventions may look very good to an inventor,

but some way or another do not suit the demands of the public. On this account, before embarking on a regular wholesale manufacture, I wanted to make absolutely sure that the new substance could be used permanently for the many different industrial purposes I had in view.

I reasoned as follows: "Here is a new material which might develop disagreeable surprises either in its process of manufacture or in its uses. Therefore, the best way is to manufacture it repeatedly on a small commercial scale for a limited number of users selected in such a way that I can watch easily the progress of their work."

As usual, I found that I had much to learn and had to change my views several times. At the beginning I had the erroneous idea that almost anybody would be able to make the new material easily, himself, and that it would simplify matters if I issued licenses on a royalty plan for the use of my patents without going myself to the trouble of any manufacturing work.

I soon found I was greatly mistaken in this, and that it would have caused no end of disappointment to teach to others chemical details which, to me, seemed rather simple, but which are easily overlooked by men who can not afford to concentrate their full attention on the subject. I concluded that a simpler way would be to sell them a partly finished product and to teach them how to use it.

But I noticed, before long, that I had to go again all through the same old experience as the introduction of *velox*. I found, to my astonishment, that people who were proficient in the manipulation of rubber, celluloid or other plastics were the least disposed to master the new methods which I tried to teach them or to appreciate their advantages. This was principally due to the fact that these methods and the properties of the new material were so different in their very essence from any of the older processes in which these people had become skilled. This rather unexpected drawback is so true that even to-day the most successful users of bakelite are just those who were not engaged in plastic before; this simply for the reason that they did not have to divorce themselves from the routine of older methods, and were willing to listen patiently to suggestions from newcomers in the field.

At the beginning I committed another mistake by trying to make the processes and the material as inexpensive as possible, using mostly the cheaper cresols, being guided by the idea that cheapness is a paramount consideration in the manufacture of plastics. It took me some time to find out that the best chances for bakelite lie where special technical effects are more important than mere cheapness, and that there is no use of wasting time and money in trying to introduce the new process in such cases where about the same results could be obtained by the older plastics. In other words, the process had to be introduced on its own merits, where, for instance, unusual strength or great resistance to heat or chemicals are essential, and not as a competitor to hard rubber, celluloid or natural resins.

The most important part of the problem we had before us was to give technical instruction to those who were willing to learn, and this technical instruction ranged from the first principles of how to use the product to all the engineering details of the equipment of their plant. It took me some time to realize that, contrary to my first intentions, it would create no end of disappointments and irregular results, and it would certainly kill the reputation of the process if every licensee were allowed to carry out, according to his own fancy, the different operations from the beginning to the end. I concluded that the best way for avoiding such a failure was to conduct the manufacture

of the raw materials to beyond the stage where chemical knowledge or too much experience is required.

At first I intended to sell the raw material unmixed with fillers, so as to let the individual user make his own molding compositions. This idea, too, had to be abandoned after I found that the proper preparation of these molding compositions in itself involved an amount of skill, knowledge and minutious care, which could hardly be expected from average workmen. Unless we followed this rule, we were exposed to clash all the time with conflicting opinions or attitudes as to what was advisable and what was not, not to mention the prejudices and petty notions of foremen or superintendents. Only after all these details had been well established and taken into consideration could I proceed to organize a complete factory, and similar establishments were started in Europe. Each of these factories was supplemented by a research laboratory and experimental department in which could be investigated the different applications of bakelite as well as the refinements in its processes of manufacture and a further general scientific study of the subject.

But even then we were soon confronted with the paradoxical situation that the greatest drawback of bakelite was its multiplicity of applications, which threatened the squandering of our efforts in too many directions at the same time. On this account, we had to adopt the policy of concentrating our attention along the lines of least resistance and to be guided somewhat by opportunities and learn when and where it was best to direct our efforts, leaving it to future opportunities for developing some of the applications which at first appeared rather attractive, but which were found to involve a disproportionate amount of attention or money for their successful introduction.

PROBLEMS CONNECTED WITH NEW CHEMICAL INVENTIONS

Most people do not realize that many new chemical enterprises present problems totally different from those connected with the running or the development of a purely mechanical industry. Indeed, some chemical processes involve factors and details which are not always easy to ascertain beforehand.

To embark upon such enterprises without testing out beforehand these factors is very much like plunging into a gambling proposition; therefore, it is better to spend the necessary money on preliminary research work and preparation, then start tentatively on a modest scale, even if it tries your patience and your pocket-book. Then after you have every right to feel sure about your proposition, there is no longer any reason for further hesitation in extending your plant to the required size.

THE IMPORTANCE OF SELECTING THE RIGHT BUSINESS ASSOCIATES

In my latter enterprise I was able not only to carry out all my preliminary work by my private resources, but I felt that, if necessary, I could run the whole commercial enterprise without the financial assistance of others. This undoubtedly put me at a great advantage, as I was not hampered by any interference with my plans. If I had looked at the narrow money side of the proposition, I might have concluded that in as far as I was practically sure of the ultimate success of this enterprise, there was no reason to divide profits by accepting financial support from others. But I had learned by former experience how very valuable it is to have the coöperation of competent men for advice or influence. Therefore, in selecting business associates for my new industry I took less in consideration any money they were willing to introduce as stockholders, than

their exceptional personal qualifications and business experience.

This point of view, on which I put great stress, is too often overlooked by chemists who start in a new enterprise where they are primarily confronted with the problem of finding the necessary funds. Frequently they make reckless connections with almost anybody who can furnish them the first money, regardless of whether they are the proper persons to help or advise or inspire them in their work, or whether they are men utterly uncongenial or who do not see in an enterprise anything but getting quickly as much cash as possible out of it, quite regardless of any other consideration.

If in the enterprises with which I have been connected I managed to get along pretty well, I can attribute it, to a large extent, to the fact that in each instance I had the good fortune of being surrounded with congenial partners or collaborators who, instead of causing friction and irritation, aroused my highest enthusiasm.

Nor do I think the grouping of business associates simply a matter of luck. It is worth some deliberation in picking out the right men. If in some instances I made a mistake, I did not hesitate to rectify it even at considerable trouble and pecuniary sacrifice. To put my opinion in a short formula, I would say: "Better do not attempt much if you have as business associates only men whom you cannot trust, or who do not trust you, or who irritate or depress you, or who are dangerous by their greed, their recklessness, their superficiality, their weak character, or their general unreliability."

CONCENTRATION OF EFFORTS

Whatever task I undertook I found it necessary to concentrate my full attention and my full enthusiasm on it, sometimes during several years in succession, until I felt I had overcome all the main difficulties connected with that line of work. During these periods of intense concentration I hardly had the time or the desire to take interest in anything else; so much did I become enwrapped in my subject that even a vacation was irksome to me, because it took me away from my favorite problem.

It was only in these periods of interval between each succeeding enterprise that I made up abundantly for all this and relaxed and was open to any other matters which might strike my fancy. Then during such intervals I lost almost entirely my interest in problems which I had successfully solved, but was ready to take up a new thing.

This explains perhaps why the different subjects with which I have been connected are so little connected among themselves, and are situated in almost opposite corners of chemistry. The very difference of the succeeding subjects contained in itself that element of novelty which fed my interest and enthusiasm. It was every time like turning a new leaf, and this prevented me from becoming too one-sided.

I should state, however, that the older I became the more cautious I was not to spend my enthusiasm on subjects which I considered unworthy of my best efforts. Several of my friends asked me, "How did you happen to strike such an interesting subject as that of the synthetic resins? I can readily answer that I did not strike it haphazardly; I looked for just such a subject for a number of years until I found it among the many lines of research which I undertook in my laboratory. More than once it has happened that at the end of years of work on some particular subject or another I had to come to the conclusion that what I had found was not worth while following up further, although it

might appear attractive enough to other chemists. So, more than once, I abruptly closed my work on some subject or another and took up another line, until finally I succeeded in finding a subject on which I could feel thoroughly enthusiastic. In this way my work became a real pleasure, regardless of whether at the end it was going to bring the results which I had expected or not.

There is no doubt that I had a decided advantage over most of my fellow chemists who cannot dispose of their time the way they please, but who are bound to certain subjects whether they like them or not. If I had remained bound to my first successful enterprise, or if I had tied myself to others in some way or another, in the desire of making money, or for other reasons, I would not have possessed, at the age of thirty-five years, that absolute freedom of my time which gave me such excellent opportunities for further study and work along more congenial lines.

DANGER OF STARTING CHEMICAL ENTERPRISES WITH INSUFFICIENT CAPITAL

A great mistake has frequently been made by chemists of starting into a new business with just enough money to get along, provided everything went well. Starting a chemical manufacturing enterprise with insufficient capital is one of the surest ways of getting caught in failure. I can say that I know of few chemical enterprises, if any, where the initial expenses were not decidedly higher than what was estimated at first.

This is usually the most critical period through which every enterprise has to pass. It happens too often that there is not enough reserve capital at hand for weathering safely through the first storms through which the newly launched ship has to navigate. It is easy enough to find all the capital when things go smoothly, but it is hard work to decide anybody to advance funds for a business enterprise which encounters troubles, except at an entirely disproportionate sacrifice. More failures in chemical enterprises have resulted from this than from almost all other causes.

PRESENT OPPORTUNITIES FOR CHEMICAL INDUSTRY IN UNITED STATES. POSSIBLE SOURCES OF FAILURE

If I have risked trying your patience by going into all these details of a rather personal nature, or by giving my opinion as to the causes of success or failure of chemical enterprises, I beg to assure you that in doing so my object lies higher than merely to pose as some kind of an example to any of you.

I want the men of this country who are desirous of joining in your chemical enterprises to realize that it is not enough to have good chemists at their disposal. I want to try to convince them that there are numerous conditions under which even the best chemists cannot possibly make a success. I would like to impress this fact upon all those who have the welfare of our nation at heart at a time when no country in the world has ever had such extraordinary opportunities for becoming foremost in all branches of chemical industry.

I ask myself: Will our present magnificent opportunities lead us to efficient development of an unprecedented advantageous position, or shall we stumble and fall through sheer blundering in the way we conduct our new chemical enterprises; will these unparalleled chances of success only result in some kind of a "flash-in-the-pan"? If we turn our present opportunities into a gigantic fiasco, then let me tell beforehand to the public at large that we should not put the whole blame on our chemists.

This country has enough able chemists, all eager to do their full share of good work. Our principal universities and engineering schools are now at least as good, for all practical purposes, as the very best European institutions of the kind. If some special branches of chemical industry as, for instance, synthetic dye manufacturing, have not attained here, in the past, the same development as in Germany, this was mostly a matter of different opportunities. On the other hand, we can point to some of our other chemical industries, where conditions were more favorable and where this country has become a leader in quantity, in quality, and in pioneership.

Shall we now strengthen our position of economic independence from foreign countries by adding new chemical industries for which heretofore there was scant inducement for the man of enterprise, alongside of much better opportunities in other directions? Shall we become what we ought to be with the abundant opportunities just now at our disposal—the greatest center of chemical enterprise of the world?

The answer to this question will depend at least as much on the kind of men who are at the business end of these new chemical enterprises as on the chemical part of the problem. In this respect I look with considerable apprehension on the future of some of the ventures which are being started now by men who are merely trying to make quick money and who, in a chemical enterprise, see only a pretext for realizing their greedy ambitions; men who look upon their chemists merely as temporary tools, ready to sacrifice their enterprise and everything connected with it as soon as they can quickly cash in their profits, instead of trying to build up a permanent establishment run along steady business lines with a good underlying financial foundation, with the purpose of insuring, for years to come, regular and lasting profits, even if they may seem more modest.

It will certainly do no harm to many of our new chemical enterprises if among their directors they have at least some chemists as well as purely business men, or bankers and lawyers. I know that such a statement will go against the belief of some of my friends who imagine that a chemist or a technical man is essentially unfit to treat a business proposition in a business-like way. If the average chemist makes a poor business man it is simply due to the fact that he seldom, if ever, has an opportunity of obtaining business experience by being allowed to participate in discussing important business propositions in the councils of the concern that employs him. I would like to ask some of our business men how they ever would have acquired business sense and business methods if they never had been allowed to learn to exercise their judgment in the handling of business problems?

It is really a sad thing to see in this and some other countries so many chemical companies where the board of directors does not comprise any chemists, except in a subordinate capacity. Why should a chemist, if he is intelligent enough to master the most intricate problems of chemistry, not be able also to learn how to exercise enough common sense and good judgment to help to discuss and devise successful business policies?

Those of the large chemical enterprises of the world, which are counted as a model in their line, have always had prominent chemists among their directors, and the policy of these enterprises has not been left entirely in the hands of a set of purely business men who remained willfully ignorant of the essential technical facts upon which their enterprise was based. I have known too many instances where serious technical difficulties were not estimated at their proper value

by ignorant directors and where serious losses, disappointments and even failure arose from that source.

Of course, it would be out of the question to expect that every director in a chemical enterprise should be a full-fledged chemist, but he ought at least, to some extent, be able to follow the difficulties, the vicissitudes and progress of the technical problems with which the enterprise is confronted. It has been my experience that intelligent business men, even if they have no technical or scientific training, can easily be made to follow with intense interest the technical questions of a chemical enterprise, provided there be among them, as fellow-directors, some chemists who can keep them informed, without going into unnecessary details, and who in doing so can speak with some authority, instead of the directors obtaining their information from subaltern employees who are often so dependent on their position that they are too timid to speak without hesitation, or to impress their views with some insistence.

OUR BANKS ILL-PREPARED FOR NEW CHEMICAL ENTERPRISES

The matter of financial support for new chemical enterprises is another subject which might be considerably improved in this country. The most successful chemical enterprises of the world have been started in a small way. At first sight this would seem an unequivocal advantage; in reality it is often a serious disadvantage from the banking standpoint. Our big banks are willing enough to back vast enterprises, but look with contempt at beginning industries. Nor have our banks the organization to enable them to investigate promptly or inexpensively the prospective merits of such small scientific enterprises.

The result is that when a chemist has a good idea he has to look for private financial backers. If he could do this directly this might be well enough, but most of the time he has to go through the intermediary of a promoter, who complicates matters considerably by interposing himself as a self-constituted middle-man, and who usually begins by diluting in advance the prospective profits of the concern, even if he does not attempt foremost to insure his own immediate benefits to the detriment of the healthy future development of the enterprise.

Before the convulsions which are now shaking Europe your ardent sympathies may lie with one or the other side of the fighting nations. But your personal likes or dislikes do not diminish the fact that Germany has set us an example in industrial preparedness and that her large banks, long ago, have mastered the art of nursing new chemical industries. Those large German banks have their staff of scientific experts, whom they freely consult about any new chemical enterprise which requests their financial support. To these scientific representatives of the bank, the chemist or inventor can talk in his own scientific language and explain clearly what he has to propose, without being barred in his appeals by the hopeless ignorance in technical or scientific matters of the bank directors, or without having to resort to the trick of playing on their imagination or hypnotize them with fairy stories and stun them with exaggerated promises.

Just imagine what it would mean here in this country for a chemist to know that he can be backed by respectable banks, in any legitimate enterprise, however small, provided he can explain to their experts, in his own way, that he has reasonable probability of success. The prestige of the bank alone would give him confidence in his work, and make him immune against the usual tactics of crushing and violent com-

petition to which his powerfully established competitors might try to subject him.

Our large American banks know how to float railroad projects, loans, real estate transactions, or to consolidate established enterprises, or issue bonds or carry out similar wholesale financial operations; but they have not yet begun to learn how to support beginning enterprises based on new scientific discoveries and which on this account can best thrive and grow to powerful maturity if allowed to be tentatively started on a small scale, provided they can reckon on adequate financial support when they need it.

THE HIGHER EDUCATIONAL EFFECT OF CHEMICAL ENTERPRISES

I would certainly not take such an intense interest in the future development of the chemical industries of this country if I looked into this matter merely from the standpoint of a so-called "prosperity" of dollars and cents. I know too well that there are easier means of making money. But I am convinced that a nation of which the prosperity is based on the development of scientific industries is bound to furnish citizens of more worthy aims than a community where people get rich by slaughtering hogs and cattle, or by speculation in the fluctuating prices of real estate, or stocks and bonds, or merchandise, or by any other occupation where gain is the exclusive purpose.

A successful industry built upon sound scientific knowledge does not mean merely dividends for its stockholders or wages for its workmen. It consists in putting in practice principles of efficiency and introducing knowledge where formerly existed ignorance, and its usual accompaniments of waste, slovenliness, misery, want, vice and sorrow. It means surrounding our life with increasing and better opportunities by using the laws of nature to the greater help of man.

Progress, in general, is very slow to grow and is still more slow to assimilate. But strange to say, our reactionary attitude has, in some cases, been cured through sheer greed. To state it brutally, science only began to make rapid progress as soon as it found applications which led to the payment of cash dividends.

Chemical and electrical companies, for instance, spend more money for research and scientific investigation than all the universities combined. The result has been that it is just those two fields of science which have shown by far the greatest development, as compared to all others. By a sort of hyperinduction, science, after helping industry, got stimulated itself by the growing exigencies of industrial enterprises.

But some of you will ask me: "Where does all this lead to; will the world at large be better for it? Are not our scientists, our chemists and engineers just those who have helped to make the present war so atrocious?" To this I can answer without hesitation, that those who are responsible for what is happening now are not the scientists themselves, even if their work has been impressed into service for means of destruction and sorrow. War is many ages older than science! Greed, iniquity, lust for power, the main inheritance of the aims and thoughts of the past, rendered respectable by a rather large share of our so-called classical literature, together with our awe for tradition, are the main influences which keep us in the cold, relentless grip of the wrong ethics of bygone ages.

Even our men of science have not been able to shake off entirely so many superstitious beliefs, so many erroneous traditions, rendered respectable through pedagogic smugness and—shall I say it—with which

the minds of the children of each succeeding generation have been mummified in prejudice of certain points of view. This accounts for the fact that the average man is still more easily swayed by elegant phrases than by scientific truths. True science, on the contrary, has no more respect for the most brilliant rhetoric of classical literature, if this latter promulgates ideals which are contrary to facts, than it has any patience with the utterances of a politician whose passion or interest makes him overlook or distort facts.

As far as the ethical side is concerned, has it ever occurred to you that, notwithstanding the fact that chemistry and electricity have enriched an enormous number of people, there are few, if any, instances where scientific men, engaged in applied science, have become as absurdly rich as some of the big money hoarders of this world? Why? Because their work is too interesting to induce them to get into a life of mere money-getting; for the chemist the financial consideration is a necessity for his existence, but that is not the chief end, as it is for those whose conception of success does not go much beyond the desire of money or power.

To him whose imagination is so rudimentary that he can perceive nothing else in the cultivation of science than dry knowledge, shrivelling up of all sentiment, I should say with Jacques Loeb (see *Yale Review*, July, 1915, "Mechanistic Science and Metaphysical Romance") that there is a sufficiently wide play for our emotions in our generous response to all that is beautiful and just and in our sympathy with all those who suffer or are treated unjustly, and that the active participation in the improvement of the masses, economically, physically, socially, intellectually and esthetically, will offer for a long time to come a sufficient outlet for all human desire for emotion. What progress the world has made, not only in physical welfare but also in the conquest of superstition and hatred, and in the formation of a correct view of life it owes directly or indirectly to exact science.

It is infinitely more costly if a mistake is made in arousing nations or social groups to hatred or fear than if a mistake is made in some special problem of physics or biology; but by an irony of fate the denunciation by society in the latter case is apt to be much more severe than in the former. This is the result of the fact that the rigid consideration of truth and the feeling of responsibility for truthfulness which exact science has established, have not yet reached the masses. And this situation will last until the influence of the metaphysical romanticist has been replaced by that of the scientist.

To you, then, and all those who are willing to build up chemical industries, let these thoughts be the guiding inspiration of your work.

My friends, chemists of America, how can I let pass an occasion like this without reminding you of what you did for me?

Twenty-seven years ago I came here as a stranger among you and now I feel so much as one of you that sometimes I wonder that there was ever a time when we did not work and play together.

When I was young and poor and unknown you never hesitated to extend to me the cordial hand of welcome, you never missed an opportunity to show me your friendliness, to help me by advice or otherwise. Much of what I have used in my work I learned from you at the meetings of our chemical societies, or in the brotherly surroundings of our Chemists' Club.

You—your friendship, your generosity, your good-natured modesty, your example, inspired me in my work. I wish I could better express my thanks.

Baltimore Meeting of the American Institute of Chemical Engineers

An account of the proceedings of the first day (Wednesday, Jan. 12) of the Baltimore meeting of the American Institute of Chemical Engineers was given in our issue of Jan. 15, page 70. The papers by Mr. H. W. Jordan, on the development of the chemical coal-products industry in this country, and by Dr. Arthur D. Little, on wood-waste utilization, which were both presented on this day, are printed in full on pages 144 and 133 of the present issue respectively.

The Barium Industry

Of the last paper of the Wednesday evening session, presented by Mr. MAXIMILIAN TOCH on "the barium industry," we herewith give a fuller account, as it also dealt in a very interesting way with broader economical problems.

A metamorphosis has come over the United States within the past eighteen months such as no one could possibly have foretold, for the manufacturing industries allied to applied chemistry have been so thoroughly upset and have undergone such tremendous changes that conditions have arisen which are unparalleled.

Ever since any one of us can remember, it has been an axiom that sulphuric acid could not be profitably shipped beyond a radius of three hundred miles. Now sulphuric acid is shipped at a cost of freight alone amounting to twice its value of two years ago, and if the condition of affairs which exists now is going to continue for another year sulphuric acid may rise to a value of from $\frac{3}{4}$ cents per pound to 8 or 9 cents per pound. I say $\frac{3}{4}$ cents a pound, knowing that contracts have been entered into in this very city of Baltimore three years ago at \$5.25 per ton, or a little over $\frac{1}{2}$ cent per pound. The great advance in the price of sulphuric acid alone is not the most unfortunate thing—the real misfortune is the fact that those of us who need it and depend upon it cannot get all we need at any price, for there isn't enough sulphuric acid made in the United States to meet the abnormal demand.

Two years ago the barium industry in the United States was unknown. True, several thousand tons of barite were imported from Germany and used on the coast of the United States for making lithopone. American barite was not used for manufacturing barium salts for the reason that the freight from Tennessee and Missouri to the Eastern coast of the United States was equal to the total cost of the barite delivered on the coast from Germany and in many instances duty paid. The prevailing price for imported barite prior to 1914 was \$5.75 per gross ton landed at tide-water duty paid. The freight from Tennessee and Missouri was between \$4 and \$5 per ton; but suddenly out of a perfectly clear sky the nations of Europe grappled each other in a death-dealing struggle, and the United States was isolated from the chemical industries of the rest of the world, and those of us who had manufactured barium salts out of foreign raw material were compelled to cast about for the American minerals or else go out of business entirely.

Mr. Toch then sketched how his firm had entered the barium industry by erecting a plant at Sweetwater, Tenn. (see page 47 of our issue of Jan. 1), and offered a strong argument for a protective tariff.

Every pioneer country—and the United States is certainly a pioneer country—demands that its laborers be paid a higher wage than is necessary in the old world's settled districts. I do not speak idly, because I have studied labor conditions in the chemical industry in many of the European States. I recall particularly the conditions as they existed in Italy before the war. The same laborer who in our factory gets \$1.75 per day, and we have a number of Italian laborers who do much of the menial work—I do not mean our factory in Tennessee, but in Long Island City, N. Y.—are the same men who get 2 lire, or 40 cents, per day in Italy. The existing conditions in the district around Rome, for instance, twenty years ago were that laborers obtained 1 lire per day and board, and the board was calculated to be not over 1 lire per day, for meat and other high priced articles of food are practically unknown there. Conditions have changed in the last twenty years until now the laborer there gets 1.50 lire and board, or 2.50 lire without board. In Germany it is just about twice this amount, and in the manufacturing districts of England about 25

per cent more than in Germany, although I am frank to say that since the war I have no knowledge of the exact wages paid, but I understand on very good information that the wages have risen very materially owing to the shortage of labor.

There is absolutely no way for compensating for these economic differences in America, excepting by means of a tariff. The question of an "anti-dumping" law might possibly work out, but it is an untried factor, and although it may have good results there is no way of telling whether it would be beneficial.

Subsidy might be another way of helping the American manufacturer, although subsidy is against the policy of the United States, and it is quite obvious that if one industry were subsidized by the United States Government by direct money grants, there probably would be a newspaper revolution, to say the least. Japan, that wonderful little country which is destined to be a wonderfully big country in time, has already both subsidized and protected her chemical industries to such an extent that eventually Japan is very likely to become an exporter of chemicals and dyes where ten years ago it practically made none.

Barite is mined in the form of natural sulphate of barium. The analysis is important. "I would rather have a barite which contains 10 per cent of harmless impurities like clay and iron than a 98 per cent barium sulphate that contains 1 per cent of fluorine and lime, for while the yield in the former composition would not be so great, the yield with an improper kind of barite would not count at all, because the lining of the furnace might be practically destroyed through the presence of noxious elements."

There are at present only four barium manufactories in the United States at the present time—one of them is manufacturing the hydrate and the peroxide in relatively large quantities. My firm has devoted its entire work to the manufacture of practically the crystalline salts, like the nitrate, chloride, some sulphate and a great deal of carbonate, and in the process which we use, sodium sulphide is a by-product, which now commands the same price as the barium salts themselves. Of course, the bottom is going to drop out of all of this if we don't get the right protection, and it will indeed be a pity if the industry will suffer.

The manufacture of the barium compounds is by no means as easy as the elementary text books indicate. One of the most difficult things that I know of—simple though it may appear on the face of it—is the manufacture of precipitated barium sulphate. The barium salts are all regarded as highly poisonous, and the probability is that they are excepting those that are insoluble, like barium sulphate; and yet pulp barium sulphate is a wonderful nutrient for micro-organisms, and I have seen most beautiful and white barium sulphate decompose and become putrid in two months, and the average fungicides or bactericides known to science have had little or no effect on them. So the chemical engineer who has had a training in bacteriology and microscopy has an advantage over the lesser trained man.

Chemists have probably regarded that there is only one barium sulphate. I now know of three various types totally different under the microscope and heterogeneous in their applications. We have long been familiar with the fact that the same chemical compounds produce very different acid salts and have totally different physical qualities, and as an example I can tell you simply that lead chromate made from potassium bichromate and lead acetate, is different in its appearance from lead chromate made from potassium bichromate and lead nitrate. The resulting chemicals are identical, but in physical aspect and in color aspect they are different. The same applies to the barium salts made of different chemicals. From time immemorial the precipitated barium sulphate of commerce has been made from barium chloride and glass makers' salt cake or neutral sodium sulphate. Since the war barium chloride has become prohibitive, and there is not enough salt cake to go around, consequently the barium sulphate made in other ways is totally different from that which we have formerly known. And so this new industry has given us new problems, costs and methods of manufacture. The scale upon which the materials are made, together with the protection which should be afforded to us by a paternal government, will in the end decide whether this industry shall live.

Business Sessions

There were two business sessions held, one on Wednesday morning, the second on Friday morning. During

the Friday session Vice-President Dr. G. W. Thompson was in the chair.

At the Friday session the result of the election of officers was announced. Dr. GEORGE D. ROSENGARTEN was re-elected president for another year, and Messrs. G. W. Thompson of Brooklyn, N. Y., A. C. Langmuir of Brooklyn, N. Y., and John M. Stillman of Stanford University, California, continue to serve as vice-presidents.

The committee on public policy offered a report in which the readiness of the American Institute of Chemical Engineers to serve the Government when its services are needed was emphasized, either in a general way or in specific matters. The report was referred to the council with power to act.

The next meeting will be held at Cleveland, Ohio, probably in the latter half of June.

One of the later meetings will be held in St. Louis, and for the St. Louis members Dr. Frerichs tendered a very cordial invitation to the Institute, and spoke eloquently of the various industrial plants which could be visited in or near St. Louis.

A technical session followed.

New Process of Bleaching

A paper by Dr. S. F. PECKHAM on "a new process of bleaching" was read in the absence of the author by the secretary, Dr. Olsen.

Some years ago someone put before Dr. Peckham the problem of bleaching flax fiber by a quick process without injury to the fiber. Some thirty years ago Charles Toppan had patented a bleaching compound of which the fixed oil of mustard and petroleum were the essential ingredients. A study of this process from all available sources led Dr. Peckham to conclude that Toppan's compound, which was originally a lubricating compound, consisted of a fixed mustard oil soap dissolved in petroleum, and that by varying the proportion his bleaching compound consisted of petroleum or its distillates dissolved in a solution of fixed mustard oil soap.

In investigating this matter further Dr. Peckham found that the different benzoles dissolve in soap solution much more readily than the petroleum distillates and that the cleansing effect on the flax fiber is marvelous. Immersion in very dilute bleaching solution produced a perfect dead white bleach and left the fiber unimpaired in strength.

This method can be successfully applied to all vegetable fiber as linen is the most difficult to bleach of all of them without injury to the fiber.

I have never seen any mention made in chemical literature that benzole and its derivatives are soluble in a solution of soap, nor did I ever hear any statement to that effect. No fixed formula can be designated as soap is soluble in water in all proportions and the stronger the solution of soap the more benzole the solution will dissolve. The formula I used was for 100 lb. of flax.

Water	50 gal.
Soap	10 lb.
Benzole	3 gal.

This was used for a heavy woven linen damask, while for ordinary light cotton, such as "gray cloth," very much less material is necessary. It need not be pure benzole, but any of the light distillates of coal tar, coke oven tar or blast furnace tar, freed from impurities by washing and proper treatment.

My invention consists of a process of bleaching by substituting for the usual lime and soda boils a single boil in a solution of soap, preferably a pure vegetable oil soap, in which is dissolved a sufficient quantity of benzole (C₆H₆) or its homologues or derivatives as found in the light distillates of coal tar and similar liquids and in light distillates of some varieties of petroleum, especially that of California as distinguished from the light distillates of paraffine petroleum. The strength of the solution in both soap and benzole would depend upon the kind and character of the ma-

terial to be bleached, light cotton fabrics requiring less than heavier cottons, and any cotton less than flax, jute or hemp.

After thorough squeezing and washing to remove the soap solution, the goods or fiber may be bleached in any known chemic, but I prefer a chemic of my own invention consisting of a solution of sodium hypochlorite, prepared by pouring together, cold, a solution of 58 per cent soda ash and a solution of calcium hypochloride, stirring the mixture and allowing it to settle. Both solutions should be prepared cold, and after mixing the solutions they should be allowed to stand at least four days or until all the available chlorine in the calcium hypochlorite shall be found in combination with the sodium and in solution. No formula can be assigned for this mixture as calcium hypochlorite varies indefinitely in strength. The quantities taken should be such that there should be a slight excess of the sodium carbonate. After a great many experiments upon this chemic I have found this method of preparation, which is very unlike any which is laid down in the books, to be the only one that will bring all the available chlorine in the calcium hypochlorite into solution as sodium hypochlorite. It is better to prepare this solution of a strength 3° to 5° Twaddle, and dilute it to such a strength that an immersion of the goods from 3 to 5 hr. will effect a bleach. After washing the bleached goods in water, they are soured, washed and calendered as usual.

By this method a complete bleach of either cotton or linen can be had in from one to two working days.

I have described a process of bleaching by which the goods or fiber are prepared for the chemic by boiling in a solution of soap in which has been dissolved a sufficient quantity of benzole or its homologues or its methylated derivatives, either separately or mixed together, as found in coal tar naphthas and similar liquids and the distillations from some petroleum as above set forth.

The soap which I have used is the cheapest that I know of on the market, as it is a by-product of the refining of cotton seed oil and is used in its crude state without further treatment.

The apparatus used is a kier with a steam jacket to which is attached an inverted condenser which returns the evaporated hydrocarbons to the kier. The process was applied on a small scale and thoroughly tested out with the most gratifying results. Of course, the goods are singed and sheared as is customary. Goods in small pieces were digested for various periods of time and the resulting goods subjected to a great variety of tests excepting the effects of time upon finished goods. It was found that if the goods were thoroughly dried after thorough washing to free them from soap the effect of the chemic was very much more satisfactory than when they were introduced into the chemic damp, directly from the squeezers. This is not surprising when very dilute solutions of chemic are used as the water remaining in the goods from the squeezers not only diluted the chemic still further but filled the pores of the goods, thus getting in the way of the chemic and preventing it from doing its work.

Lutes and Cements, and Water Purification by Ozone

A paper by Mr. S. S. SADTLER of Philadelphia on "lutes and cements for chemical purposes" was next presented. In the absence of the author it was read by the secretary, Dr. Olsen. This interesting and useful paper will be published in full in our issue of Feb. 15.

The last paper of this session was presented by Mr. POWELL, on the system of water purification by ozone employed by the Baltimore County Water Company. The system was developed by their chief engineer, Mr. Walton, and its most interesting feature is the use of aluminium electrodes and micanite tubes for the dielectric. The over-all cost of purification is below \$2 per 1000 cu. ft. of water.

Friday Evening Session and Excursions

For the evening of Friday a joint meeting with the Maryland Section of the American Chemical Society had been arranged, the program comprising a paper by Dr. G. W. THOMPSON on changes in the volume and specific gravity of linseed oil films on drying and a paper by Dr. H. E. IVES on artificial daylight. This was followed by a smoker at the Johns Hopkins Club, given by the Maryland Section of the American Chemical Society.

A very fine program of excursions had been arranged. On Wednesday afternoon two different parties were formed; one visited the Maryland Steel Company's plant at Sparrow's Point, the other the Baltimore sewage disposal plant and the ozone water purification plant.

On Thursday an all-day excursion was made to Annapolis.

On the evening of Thursday a subscription dinner was held at the Emerson Hotel. It was well attended and very enjoyable. Dr. Charles F. McKenna was a brilliant toastmaster.

On Friday afternoon three excursions were made. One party visited the Standard Fertilizer Works and the Davison Chemical Works, the latter being one of the largest sulphuric acid plants and containing much of considerable interest. Another party visited the Maryland Glass Corporation, and a third party the new buildings of Johns Hopkins University.

The chief excursion on the program for Saturday was to the Tidewater Portland Cement Company at Union Bridge, Md.

Synopsis of 1915 Mineral Production

From advance estimates of the production of ores and metals in the United States, made by the U. S. Geological Survey, we abstract the following essential data:

In the Western states alone the metal production shows an increase in value of more than \$130,000,000 over the corresponding figures for 1914; and the year's increase in output for the principal metals measured in value is more than \$250,000,000. Moreover it is not unreasonable to expect that when the full returns for all mineral products are compiled they will show that 1915 was the country's most productive year in the mining industry. The total may even reach two and one-half billion dollars.

The copper mines passed all records for previous years, the 1915 output having a value of \$236,000,000, or \$83,000,000 more than the value of the production for 1914. The statistics and estimates received place the output of blister and Lake copper at 1,365,500,000 lb. or more than 120,000,000 lb. in excess of the largest previous production and 18 per cent above last year's figures. Only twice in the history of copper mining has there been a larger increase in quantity of metal produced.

The total shipments of iron ore from the mines in the United States in 1915 are estimated to have exceeded 55,000,000 gross tons, an increase over 1914 of more than 38 per cent. Based on the same price as received in 1914 this represents an increase in total value of about \$27,645,000. The increase in pig iron is estimated at 6,500,000 tons, with a total increase in value of pig iron production of more than \$120,000,000.

The output of zinc (spelter) made from domestic ores was larger than ever before, being about 425,000 tons, worth \$120,000,000, as compared with 343,418 tons in 1914, an increase of about 82,000 tons, or nearly 25 per cent in quantity and of \$85,000,000 in value. Production was increased during the latter half of the year, as the production during the first half was at the rate of 415,000 tons annually and at the rate of 436,000 tons during the last half.

The output of refined pig lead from domestic ores was about 515,000 tons, worth about \$48,500,000, as compared with 512,794 tons in 1914, an increase of only 2500 tons in quantity but of \$8,500,000, or 20 per cent in value. The production of antimonial lead was 20,550 tons, as compared with 16,668 tons in 1914, an increase of 3882 tons or 23 per cent in quantity and an increase in value of nearly \$2,000,000.

The annual preliminary estimates on the production

of gold and silver in the United States, made jointly by the United States Geological Survey and the Bureau of the Mint, are not yet complete, but early figures based on reports from the mines indicate an increase in mine production over that of 1914 of over \$7,000,000 in gold, principally from Colorado, California, Alaska, Montana and Idaho, and an increase in mine production of silver of fully 4,000,000 ounces, chiefly from Montana, Utah and Arizona. This increase in gold production may bring 1915 up to the record year of 1909, when the gold output of this country was nearly \$100,000,000.

Quicksilver also has had its best year in 1915. The quantity increased 25 per cent over 1914, but the value of the output more than doubled owing to the much higher prices. The estimated production was 20,681, flasks of 75 lb. each, valued at the average price for the year—the highest in the last forty years—at \$1,768,225. In value, this domestic production was the highest since 1881 and in quantity the largest since 1912.

Arizona

The output of gold, silver, copper, lead and zinc at mines in Arizona in 1915 was valued at \$88,551,000, according to the United States Geological Survey, an increase of nearly 48 per cent over that of 1914, which was \$59,956,029. There was very little change in the output of gold, but there were notable increases in the other metals, especially in lead and zinc. Increased prices made a difference of nearly \$26,000,000 in copper, \$400,000 in lead, and over \$2,000,000 in zinc. The output of gold in Arizona mines increased about 1 per cent over that of 1914, which was \$4,179,155. A record production of silver was made, the output increasing from 4,377,994 oz. in 1914 to about 5,458,000 oz. in 1915, or over 24 per cent. The value of this output increased about \$2,718,000. Arizona is the leading copper-producing State of the country and had an output of nearly 450,000,000 lb. in 1915, an increase in quantity of nearly 57,000,000 lb. and in value of nearly \$26,000,000. The mine output of lead increased from 15,003,068 lb. in 1914 to about 22,272,000 lb. in 1915, an increase of over 48 per cent. The value increased from \$585,120 to \$1,033,000. The mine production of zinc, estimated as recoverable spelter, increased from 9,792,337 lb. in 1914 to about 17,729,000 lb. in 1915, an increase of 81 per cent. The unusual average price of zinc for 1915 gives a value of about \$2,524,000 to this product.

California

California mine figures for 1914 were \$20,653,496 in gold and 1,471,859 fine ounces of silver; the estimates for 1915 indicate an output of \$22,860,590 in gold and 1,974,529 oz. of silver, an increase of \$2,207,094 in gold and 502,670 fine ounces of silver. California remains the premier gold-producing State of the country. The yield for 1915 is the largest in thirty-two years and with one exception the largest in fifty-one years.

The silver output from the mines shows an estimated increase in 1915, as compared with 1914, of 502,670 oz. The estimated mine yield of copper in 1915 is 44,098,552 lb., as compared with 30,507,692 lb. in 1914, an increase for 1915 of 13,590,860 lb. The mine output of lead in 1914 was 4,251,923 lb.; in 1915 it is estimated at 6,346,319 lb., an increase for the latter year of 2,094,396 lb. The estimated zinc output of the State in 1915 is 11,443,926 lb., against 389,471 lb. in 1914, an increase for 1915 of 11,054,455 lb. This is the largest production of this metal ever made in California in one year.

Colorado

The mine output of Colorado metals for eleven months of 1915, with an estimate for December, indi-

cates a yield for the year of \$22,330,000 in gold, 7,080,000 oz. of silver, 66,664,000 lb. of lead (in terms of lead bullion and lead in leaded-zinc oxide), 7,100,000 lb. of copper, and 100,000,000 lb. of zinc (in terms of spelter and zinc in zinc oxide), with a total value of \$43,100,000, compared with \$19,883,105 in gold, 8,796,065 oz. of silver, 74,211,898 lb. of lead, 6,639,173 lb. of copper and 96,774,960 lb. of zinc, with a total value of \$33,460,126 in 1914. This shows an increase of \$2,447,000 in gold, decreases of 1,716,000 oz. of silver, and 7,550,000 lb. of lead, an increase of 306,000 lb. of copper and 3,200,000 lb. of zinc. With the increased average value of metals, except silver, the values show a decrease of \$1,380,000 for silver, an increase of \$300,000 for lead, an increase of \$340,000 for copper, and an increase of \$8,065,000 for zinc.

Idaho

The output of gold, silver, copper, lead and zinc from ores sold or treated from Idaho mines in 1915 had a total value of about \$37,780,000. This is an increase of more than 53 per cent over the production of 1914, which was valued at \$24,645,848. There was no great change in the output of gold and a slight increase in that of silver, but there were material increases in the production of copper, lead, and zinc, especially of zinc. The increase in the total value of these metals, amounting to over \$13,000,000, was due largely to the increased price of lead and zinc. The mine production of gold was nearly the same as that of 1914, valued at \$1,152,315. The production of silver increased from 12,479,516 oz. in 1914 to about 13,000,000 oz. in 1915, or more than 4 per cent. The price of silver, however, was comparatively low and the value of the output was over \$400,000 less than in 1914. The output of copper was increased from 6,445,187 lb. in 1914 to about 7,169,000 lb. in 1915. The mine output of lead, which is the main mineral product in Idaho, increased from 348,526,069 lb. in 1914 to about 377,000,000 lb. in 1915. Shipments of zinc ore and concentrate increased from 54,754 tons in 1914 to about 97,000 tons in 1915. The shipments contained about 80,000,000 lb. of recoverable spelter, valued at over \$11,000,000. On account of the unusual price for zinc in 1914, the zinc produced in the State was more valuable than the gold, silver, and copper combined.

Montana

The value of the output of gold, silver, copper, lead and zinc from Montana mines in 1915 was nearly \$87,000,000, an increase of more than 81 per cent over the total value of the same metals in 1914, which was \$47,849,747, and is the greatest annual value of metals produced in Montana. There were increases in the output of all metals, but especially of lead and zinc. Though quantities show increases, the large increase in value was even more the result of a great rise in prices. The mine output of gold was valued at nearly \$5,000,000, against \$4,117,911 in 1914, an increase of over 21 per cent. The mine output of silver increased from 12,016,460 oz. in 1914 to about 14,500,000 oz. in 1915. This output shows an increase of nearly 21 per cent and is even greater than that of 1913, which was the record up to that time. Montana's greatest asset is copper, the output of which increased from 233,229,640 lb. in 1914 to nearly 275,000,000 lb. in 1915. This was an increase of nearly 18 per cent over 1914, but the output did not reach that of 1913. The mine output of lead increased considerably—from 9,656,008 lb. in 1914 to slightly over 14,000,000 lb. in 1915. This increase of over 45 per cent was due largely to the shipment of lead concentrates and of residues resulting from zinc smelting. The mine production of zinc increased from 111,-

580,544 lb. (figured as spelter) in 1914, to 184,086,000 lb. in 1915. The spelter output represented an increase of nearly 61 per cent in quantity, but as the price of the metal increased from 6.30c. in January to 22.2c. in June there was an increase in the value of the output from \$5,690,608 in 1914 to over \$26,000,000 in 1915.

Nevada

The 1915 output of gold, silver, copper, lead and zinc from Nevada mines was approximately \$34,566,000. This represents an increase of nearly 18 per cent over the output of 1914, when metals valued at \$29,300,842 were produced. These estimates indicate a marked increase in zinc output, and increase in lead and copper yield, as compared with 1914. The copper production however was below that of 1913, when Nevada had a record output of over 90,000,000 lb. There was a slight increase in the gold production, but a decrease in silver. The production of gold was valued at about \$11,968,000, an increase of 4 per cent over the production of 1914. The silver production decreased from 15,455,491 oz. in 1914 to about 14,478,000 oz. in 1915. The mine production of copper increased from 60,986,450 lb. in 1914 to about 67,480,000 lb. in 1915, an increase of 10.6 per cent. The total value of the output, on account of the high average price in 1915, increased from \$8,111,198 to approximately \$11,708,000. The lead production increased from 12,809,655 lb. in 1914 to about 14,782,000 lb. in 1915, an increase of over 15 per cent. This output, however, is not as great as that of 1913, when over 16,000,000 lb. were produced. A great increase, nearly 62 per cent, was made in the mine output of zinc in Nevada, from 12,980,232 lb. of recoverable spelter in 1914 to over 21,000,000 lb. of the metal in 1915. As the price of the metal was abnormally high in 1915, the value of the output increased from \$661,992 to about \$2,993,000 in 1915.

New Mexico

The output of New Mexico mines for eleven months of 1915, with an estimate for December, indicates a yield of \$1,500,000 in gold, 2,032,000 oz. of silver, 3,951,000 lb. of lead, 72,000,000 lb. of copper, and 24,640,000 lb. of zinc (in terms of spelter and zinc in zinc oxide), as compared with \$1,171,696 in gold, 1,777,445 oz. of silver, 1,763,641 lb. of lead, 59,307,925 lb. of copper and 18,403,392 lb. of zinc in 1914. These preliminary figures show an increase of \$328,000 in gold, 255,000 oz. of silver, 2,186,000 lb. of lead, 12,674,000 lb. of copper, and 6,237,000 lb. of zinc. With higher values of metals, except for silver, the total value was \$18,277,000, against \$11,049,932 in 1914, an increase of \$7,226,660.

Oregon

Preliminary estimates of the output of metals from Oregon mines in 1915 show material increases over the figures of 1914 in both gold and copper, and slight decreases in yield of silver and lead. The gold yield for 1914 was \$1,591,461 and the estimate for 1915 is \$1,771,618, which is an increase of \$180,157 for 1915. The silver output for 1914 was 142,552 oz., and the estimate for 1915 is 136,033 oz., or 6519 oz. less. The yield of copper in 1914 was 39,248 lb., while the estimate for 1915 is 910,104 lb., an increase for 1915 of 870,856 lb.; and the yield of lead was 16,436 lb. in 1914, as compared with 6650 lb. in 1915, or 9786 lb. less.

South Dakota

The mine production of gold from South Dakota in 1915 was \$7,390,000, compared with \$7,333,508 in 1914, and that of silver was 193,000 oz., compared with 176,642 oz. in 1914. A nominal quantity of lead was produced. Since 1876 South Dakota has produced \$192,677,000 in gold, and 6,026,000 oz. of silver.

Utah

Mines in Utah produced gold, silver, copper, lead and zinc in 1915 amounting in value to \$55,000,000. This represents an increase over the production in 1914 of nearly 50 per cent, or \$18,000,000. There was a considerable increase in all the metals. About one-fourth more ore was mined, increasing the total from 8,544,014 tons in 1914 to about 10,725,000 tons in 1915. The mine output of gold increased over 19 per cent—from \$3,265,347 in 1914 to \$3,908,000 in 1915. The mine production of silver increased from 11,54,916 oz. in 1914 to approximately 12,724,000 oz. in 1915, the increase amounting to 14 per cent in quantity and about \$169,000 in value. The copper output from Utah mines increased from 152,034,002 lb. in 1914 to about 182,589,000 lb. in 1915, the increase amounting to more than 20 per cent in quantity and about \$11,450,000 in value. The gain was made mostly by the Utah Copper mine at Bingham, which is credited with an increase of 34,207,552 lb. over the output of 1914. The mine production of lead increased from 171,323,137 lb. in 1914 to 219,098,000 lb. in 1915, or about 28 per cent. With the advance in prices, zinc ore was offered from many sources. The mine production of zinc recoverable as spelter aggregated 22,643,000 lb., valued at about \$3,224,000. This is an increase of about 41 per cent in quantity over the output of 1914, amounting to 15,989,267 lb.

Washington

The value of the mine output of gold, silver, copper, lead and zinc in Washington decreased from \$809,767 in 1914 to approximately \$728,000 in 1915. There were increases in copper and lead, to the extent of a return to normal production. There were shipments of zinc ore, the first since 1911. The gold and silver mines, however, showed decreased output, especially in the Republic mining district. The mine production of gold, which is the most important metal of the State, decreased from \$557,173 in 1914 to about \$407,000 in 1915. The silver output decreased from 264,861 oz. in 1914 to about 220,000 oz. in 1915. The production of lead from ores sold or treated increased from 65,507 lb. in 1914 to about 230,000 lb. in 1915. The mine output of copper increased from 778,723 lb. in 1914 to about 915,000 lb. in 1915, or over 17 per cent. On account of the increased price of the metal, the value increased from \$103,571 to about \$159,000 in 1915. The production was not as great as the production of either 1913 or 1912. The zinc output was entirely from the Metaline district, Pend Oreille County, where the Lead-Zinc Company operated a 50-ton concentration mill the latter part of the year. Several hundred tons of sulphide concentrates were shipped, together with some carbonate ore.

Synopsis of Recent Chemical and Metallurgical Literature

Gold and Silver

Hydrolysis of Cyanide and Value of Protective Alkali.—In the July-August, 1915, issue of the *Journal of the Chem. Met. & Min. Soc. of S. Africa*, Dr. JAMES MOIR contributes some data on this subject, showing that, roughly speaking, the addition of alkali equal to one-tenth of the cyanide causes the recovery of 90 per cent of the lost cyanide. The hydrolysis of sodium cyanide in water is due to the weakness of HCN as an acid, resulting in NaOH and HCN existing uncombined in any solution of NaCN. The table gives the quantities and percentages of HCN and NaOH for any strength of total cyanide. Hydrolysis is less in the

presence of zinc cyanide, but the author does not know how much.

TABLE I

Hydrolysis of pure NaCN into HCN and NaOH at summer temperature. (Results 10 per cent to 15 per cent lower in winter.) Y = total cyanides per cent as KCN. Z = part hydrolyzed to HCN, but calculated as KCN per cent. Z = part hydrolyzed to NaOH calculated as per cent NaOH.

		100Z		
Y	x	Y Per Cent of Whole	Z Per Cent Total KCN	
1.0	0.0077	(0.8)	0.0047	(0.5)
0.5	0.0054	(1.1)	0.0033	(0.7)
0.3	0.0042	(1.4)	0.0026	(0.9)
0.2	0.0034	(1.7)	0.0021	(1.1)
0.1	0.0024	(2.4)	0.0015	(1.5)
0.05	0.0017	(3.4)	0.00105	(2.1)
0.02	0.0011	(5.4)	0.0007	(3.3)
0.01	0.0008	(7.7)	0.0005	(4.7)
0.005	0.0005	(11)	0.00033	(6.7)
0.001	0.00024	(24)	0.00015	(15)

There is some doubt whether Clennell's process tried on pure KCN would indicate the alkalinity due to hydrolysis. Assuming that it does *not* do so, but only added alkalinity, the formula

$$x_i = \frac{Y}{27,500(W + Z)}$$

gives the HCN (calculated as KCN) in presence of "Clennell-alkalinity" of W per cent. Thus if W = 0.01 per cent NaOH and Y = 0.5 per cent KCN, Z from above table is 0.0033, total alkalinity (W + Z) = 0.0133 and $x_i = 0.0014$ per cent (about one-quarter of hydrolysis in absence of NaOH, see x above). The following table has been constructed from this formula for all common strengths of cyanide.

TABLE II

Hydrolysis in presence of extra alkali.		Amount of HCN Lost by Hydrolysis Calculated as Per Cent	
Strength of Cyanide as KCN Per Cent	Observed Alkalinity as NaOH Per Cent	Y	Z
0.2	0.03	0.00023	0.00033
	0.02	0.00033	0.00033
	0.01	0.00050	0.00033
	0.005	0.00102	0.00033
	0.002	0.00177	0.00033
0.15	0.03	0.00017	0.00025
	0.02	0.00025	0.00025
	0.01	0.00046	0.00025
	0.005	0.00080	0.00025
	0.002	0.00144	0.00025
0.10	0.03	0.00012	0.00017
	0.02	0.00017	0.00017
	0.01	0.00032	0.00017
	0.005	0.00056	0.00017
	0.002	0.00104	0.00017
0.05	0.03	0.00006	0.00009
	0.02	0.00009	0.00009
	0.01	0.00016	0.00009
	0.005	0.00030	0.00009
	0.002	0.00050	0.00009
0.02	0.03	0.000024	0.000036
	0.02	0.000036	0.000036
	0.01	0.000072	0.000036
	0.005	0.000144	0.000036
	0.002	0.000352	0.000036

Antimony

Behavior of Stibnite in Oxidizing Roast.—A study of the behavior of stibnite, Sb_2S_3 , under the conditions of an oxidizing roast has been studied by H. O. HORMAN and JOHN BLATCHFORD, who communicate their results in the January *Bulletin of the American Institute of Mining Engineers*. Certain difficulties inherent in stibnite are encountered in the oxidizing roast. It has a low melting point, 540 deg. to 550 deg. C., according to various authorities; the ignition point is still lower, the mineral beginning to oxidize at 290 deg. C. if the size of grain is 0.1 mm., and at 343 deg. and 430 deg. respectively for gains from 0.1 to 0.2 mm. and 2 mm.; a mixture of Sb_2O_3 and Sb_2S_3 is fusible at 517 deg. C.; both of the latter compounds are volatile at low temperatures.

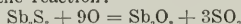
The aim of the present investigation was to study the changes undergone by stibnite when roasted at

different temperatures; the composition of the roasted product; the losses which occur. The roasting furnace used was of the electric resistance type. The following table gives a summary of observations during the experiments.

Temperature, °C.	Changes
196	Faint odor of SO_2 .
219	Litmus begins to turn pink.
281	Ore becomes dull; odor of SO_2 very distinct.
336	White ashes form on rubbing, and some Sb_2O_3 is evolved.
380	Lowest temperature at which odor of SO_2 disappears.
400	Ore becomes sticky if temperature is raised quickly.

The conclusions drawn by the authors are:

1. The ignition point of stibnite is approximately 200 deg. C., as evidenced by the odor of SO_2 evolved and its action on litmus paper.
2. There is a sharp visible formation of Sb_2O_3 at 336 deg. C. At this point white fumes are evolved.
3. The formation of Sb_2O_3 takes place slowly, probably according to the reaction:



4. It is possible to eliminate all the sulphur slightly below 400 deg. C. without a large loss of antimony.
5. Stibnite is oxidized at first to antimony trioxide which begins to change to antimony tetroxide only when all the sulphide has been decomposed.
6. The amount of tetroxide increases as the trioxide decreases, the action being more rapid as the finishing temperature is raised.
7. The loss of antimony during the roast increases with the temperature.

Determination of Antimony in Roasted Stibnite.—In a paper to be presented at the February meeting of the American Institute of Mining Engineers, W. T. HALL and JOHN BLATCHFORD describe their methods for determining the condition of the antimony as well as the total quantity present in roasted stibnite. The roasted product may contain some unoxidized Sb_2S_3 and a mixture of Sb_2O_3 and Sb_2O_4 .

Total antimony was determined as follows:

Weigh out 0.25 gram of the roasted product into a trapped flask, add 4 grams of powdered tartaric acid, 2 grams of potassium iodide and 40 c.c. of concentrated hydrochloric acid. Boil the solution gently for 5 minutes and then cool to room temperature by shaking the flask while holding it under running water. Then, very carefully discharge the iodine color by the cautious addition of 0.05-normal sodium thiosulphate solution, adding a little starch toward the last. Nearly neutralize the acid with ammonia solution, but leave the solution distinctly acid. Pour the slightly acid solution into 200 c.c. of water containing an excess of sodium bicarbonate and titrate to a permanent blue color with standard 0.1-normal iodine solution.

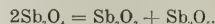
The determination of the unchanged antimony sulphide was accomplished by a method corresponding to that used in the determination of sulphur in steel. The sample was dissolved in concentrated hydrochloric acid, the escaping hydrogen sulphide absorbed in an ammoniacal cadmium chloride solution and the sulphur in the precipitated cadmium sulphide determined iodometrically.

Inasmuch as all the antimony present in the roasted stibnite was soluble in concentrated hydrochloric acid, the solution remaining in the evolution flask after the determination of the sulphur could be used for the determination of the trivalent antimony. The details of the procedure are as follows:

To the solution remaining in the evolution flask after the determination of the sulphur, add 4 grams of powdered tartaric acid and carefully dilute with 100 c.c. of water. Carefully add 6-normal ammonia solution until

the solution is only slightly acid and then pour the solution into a large beaker containing 5 grams of sodium bicarbonate in 200 c.c. of water. Titrate with 0.1-normal iodine solution as in the determination of the total antimony.

In computing the results, it is necessary to remember that antimony tetroxide may be regarded as antimonious antimonate:



Since antimony pentoxide changes to the tetroxide when heated above 300 deg., it is fair to assume that each atom of pentavalent antimony found in the analysis corresponds to one molecule of antimony tetroxide. Then from the total quantity of trivalent antimony found, deductions must be made for the amount of tetroxide and for the trisulphide as found by the sulphur determination, the balance is the trivalent antimony corresponding to the quantity of antimony trioxide present.

Recent Chemical and Metallurgical Patents

Silver-Palladium Alloy, Substitute for Platinum.—An alloy for use in contact and spark devices to replace platinum is patented by Mr. PAUL R. HEYL of New Rochelle, N. Y. (assigned to Commercial Research Company of New York City). This alloy consists of silver and palladium in varying proportions according to the conditions under which it is to be used. An alloy of silver with 2 per cent of palladium has been found to give satisfactory results under many circumstances. When the contacts or spark points are exposed to sul-

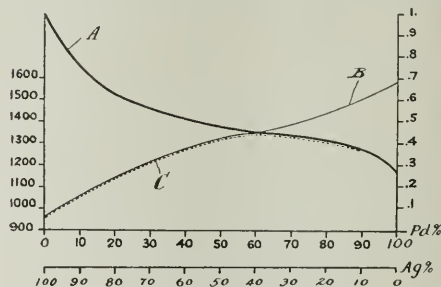


FIG. 1—SILVER-PALLADIUM SERIES

phur compounds 5 per cent or more of palladium should be used. The alloy which was found to give the greatest resistance to spark erosion was that of 60 per cent palladium and 40 per cent silver. Palladium has a higher melting point and lower thermal conductivity than silver, consequently additions of palladium to silver raise the melting point and lower the thermal conductivity. It has been found that, on account of the high thermal conductivity of silver, the heat from the spark will be conducted away fast enough to prevent melting of the silver. In view of this fact silver-palladium alloys with very high percentages of silver can be used in a great many cases. A diagram of the silver-palladium series is shown in Fig. 1. Curve B is the melting point curve, A is the thermal conductivity curve, and curve C (shown dotted) was constructed to illustrate the resistance to spark erosion, although this may vary under different conditions. The maximum resistance to spark erosion is seen to be at substantially 60 per cent of palladium and 40 per cent of silver. Different desirable degrees of softness may be obtained with these alloys (1,166,129, Dec. 28, 1915).

Iron Alloy.—An alloy possessing properties which will permit of its being used to produce cast chilled rolls

and sand rolls that possess an extremely hard surface and strong central portion is patented by HERBERT E. FIELD and FRED. C. T. DANIELS of Wheeling, W. Va. The chilled surface of rolls made of this alloy is claimed to be so hard that it cannot be machine finished, but must be finished by grinding machines, and the central portion will withstand shocks and strains even when heated in the hot working of iron and steel. The composition of the alloy is as follows: silicon, 0.250 to 1.50 per cent; sulphur, 0.025 to 0.20 per cent; phosphorus, 0.010 to 1.00 per cent; manganese, 1.50 to 3.50 per cent; carbon, 1.50 to 3.50 per cent, and iron to make 100 per cent. The alloy may also contain small quantities of other elements, such as vanadium, titanium, tungsten, copper, or cobalt. The alloy is made in the usual way (1,166,342, Dec. 28, 1915).

Cathode Starting Sheets.—In producing cathode starting sheets as in electrolytic copper refining it has been customary to make a scratch groove on both surfaces of the blank and at a short distance from the edges. This groove is made of sufficient depth to permit a skilled operator to detach the deposited starting sheet along the groove. The undetached metal between the grooves and the outside edges has to be scrapped and remelted. Considerable time is also required to remove these edge strips. Making a scratch groove on the edge did not obviate these difficulties as the metal bridged over the groove to such a degree as to firmly unite the deposits on the opposite sides of the blank. In order to do away with the expense of remelting the scrap, and also to provide an easily detachable starting sheet, a new method is patented by EDMOND A. GUGGENHEIM of New York. In this method an insulating material is placed in a recess all around the outer edges of the blank so as to prevent metal from depositing on this insulated section. The lower edge may or may not be insulated, but it is grooved in any case. Some of the insulating materials mentioned are asphaltum, asphaltum mastic and chattron compound. The methods of insulating the side and bottom edges and of grooving the bottom edge are shown in Fig. 2 (1,163,337, Dec. 7, 1915).

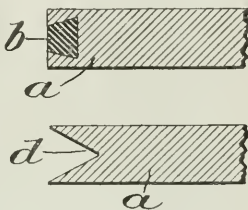


FIG. 2—CROSS-SECTION OF SHEETS

Electrolysis of Zinc Solutions.—Addition of calcium carbonate to zinc chloride or zinc sulphate solutions is claimed to aid in the deposition of commercial metallic zinc, according to a patent of CLARENCE A. HALL of Mount Airy, Pa. The process does not require any marked departure from ordinary practice as to current density, and diaphragms are not necessary. Finely divided calcium carbonate in quantity sufficient to unite with the liberated sulphate or chlorine ions is added to the bath and kept in a suspended condition by agitating. It is claimed that this addition will prevent the deposition of mossy zinc (1,163,911, Dec. 14, 1915).

Electric Furnace for Melting and Heat Treating.—An electric furnace designed to reduce heat losses through radiation to the furnace walls is patented by JAMES M. LOHR and HORACE W. GILLET of Ithaca, N. Y. Several different styles of this furnace are mentioned, all embodying the same idea of subdividing the furnace into several compartments and using as heating elements the dividing partitions. Some of the styles described are a long, narrow furnace, a triangular-shaped furnace, and a furnace in the shape of an an-

nular ring. By dividing these furnaces into several compartments and using the dividing partitions as heating elements, the direct radiations from both sides of these elements will strike the crucible placed in the compartments, whereas in the old form of furnace one side of the heating element usually radiated heat directly to the furnace wall. The use of the idea has been generously thrown open to the public by the patentees (1,162,178, Nov. 30, 1915).

Reverberatory Smelting Furnace.—In Fig. 3 we illustrate a method of fettling reverberatory furnaces from hoppers placed along the sides of the furnace, patented by GEORGE C. CARSON of Denver, Colo. The

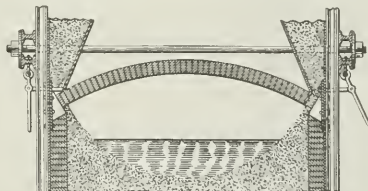


FIG. 3—REVERBERATORY FURNACE

object of the invention is to improve the former method of protecting the side walls of the furnace by hand-fettling or claying. According to the present invention, it is proposed to feed refractory material to the side walls by gravity from hoppers which are placed above the furnace and which have communication with the interior. (1,149,495, Aug. 10, 1915.)

Roasting Furnace.—A furnace structure patented by UTLEY WEDGE of Ardmore, Pa., is shown in elevation in Fig. 4. It has fixed annular walls 1 and 2, between which is a furnace chamber 3. Within the chamber is a series of superposed annular hearths, some of which, as at 4, are stationary and project from the walls, while others, as at 5, are rotatably mounted on

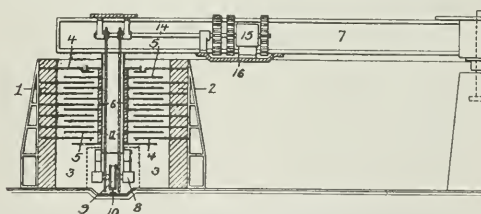


FIG. 4—ROASTING FURNACE

a structure 6 in the center of the roasting chamber. This structure is connected to the arms of a spider 7, which turns about an axis concentric with the annular structure of the furnace. The hearths have rabbles on their under sides for stirring and moving the ore on the hearth beneath. The annular structure 6 is composed of sections each provided with a pair of trucks 8 and wheels 9 which run on the track 10, and thus support the structure. Rotation of the spider is accomplished by power from a motor 15, communicated by a train of gearing and shaft 14 to drive chains 12, which turn the wheels 10. (1,159,141, Nov. 2, 1915.)

Method of Cooling Roasted Ore.—For the purpose of cooling the product of a prerosting furnace of the Godfrey type, which product is to be further treated by sinter-roasting, WILLIAM H. HUBBARD, JR., of Salida, Colo., has devised and patented apparatus which avoids the annoyance of dust and smoke and brings the ore into good physical condition for handling and further treatment. It consists of a circular table onto which

the hot ore is delivered and rabbled. The table may be rotatable and the rabbles stationary, or vice versa. (1,149,264, Aug. 10, 1915.)

A Novel Cooler

Though the roasting of ore, cement clinker, etc., has received the closest attention and study, the after-cooling of hot, and oftentimes semi-molten, material has generally been left to the crudest of devices. Instead of special and ample space being reserved, the cooler is fitted as an afterthought into some corner or pit, and its design also receives slight attention. Imperfect cooling, followed by rapid vulcanizing of conveyor and elevator belts and injury to chemical solutions, inevitably takes place, not to speak of the power, repair parts, cooling water, grease, etc., wasted on a machine avoided by the attendants on account of poor location, dust and heat.

Recognizing this difficulty, the engineers of one of the largest users of roasters in the world, by experiment and investigation, systematically undertook its solution. The evolution of the "Baker" cooler, patented by Mr. F. D. Baker, chief engineer of the American Smelting & Refining Company, and illustrated above, is the direct result of this work.

Red-hot material is fed continuously through a cast-iron or steel spout into one of the cone-shaped ends of a steel cylinder. This cylinder is partly submerged in a bath of water contained in a concrete, rectangular tank. The amount of submergence is adjustable, and is carefully calculated so that the weight, not only of the cylinder, but also of its load of cooling material, floats on the water by displacement. Friction, and consequently power, is therefore reduced to a minimum, and end bearings are used only as guides and to prevent the cylinder rising in case the load is reduced.

The cylinder revolves very slowly and the hot material is advanced by means of plows. The heat is transmitted to the steel shell, which is an excellent conductor. Part of it immediately passes into the water-bath, but most effective absorption takes place on that part of the shell above the bath during the evaporation of its covering of water. In proportion to the total circumference the portion of the shell in contact with the hot material at any one time is small, therefore damage to the shell by overheating is impossible, as even during a shutdown it is water-jacketed.

Discharge is effected by means of a spiral which raises the cooled material to practically the same level

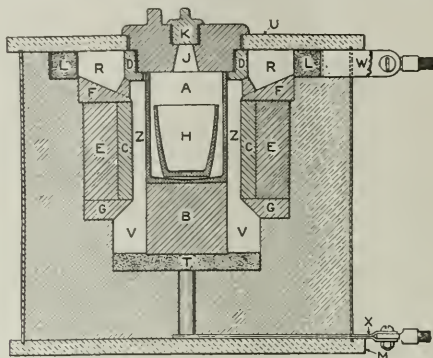
as it enters the cylinder, thereby conserving head room.

The final temperature is regulated by the rate of feed, by the peripheral speed of the cylinder, and by the angle and number of plow-blades.

Though originally designed for the cooling of roasted ores, the Baker cooler has been most successfully applied to the cooling of bauxite, soda-ash and other industrial materials. It is manufactured by the Stearns-Roger Mfg. Co. of Denver, Col.

American Made Laboratory Glassware

A borosilicate glass, called pyrex, which was developed by the Corning Glass Works has proved itself equal to all demands made upon laboratory glassware. This glass possesses a very low coefficient of expansion (0.0000032) and great resistance to sudden temperature



HIGH-TEMPERATURE EXPERIMENTAL FURNACE

changes. Tests made on this glass show it to be less soluble in water and acids than the best glass heretofore made and about equally soluble in alkalies. On account of the low coefficient of expansion it has been possible to make the glassware with thicker walls than usual, thus adding to the mechanical strength. This glassware is handled in the east by Eimer & Amend in New York City and Arthur H. Thomas Co., Philadelphia, Pa.

Experimental Electric Furnace for High Temperatures

An electric furnace which was designed primarily for determining the fusion point of coal ash, metals and alloys, but which has also found application in other experimental work is shown in section in the accompanying illustration. This furnace is known as the "High Temp" furnace and is sold by Eimer & Amend, New York City.

Under normal heats the furnace reaches 1600 deg. C. in about one hour and has a maximum temperature limit of 1800 deg. C. Referring to the illustration, Z represents the heating zone formed by two concentric cylinders A and B inside, and C outside the zone. A special granular resistor material is used which is placed in the chambers R, Z and V. The portions R and V have large area and lower resistance than V, consequently the heat is concentrated in the zone Z.

Graphite electrodes are shown at L and T. These form contact with the granular resistor material. The resistor material is gradually replaced as it is used up.



COOLER

A demonstration of one of these furnaces was made at the National Exposition of Chemical Industries held last September in New York. A furnace was run continuously for a week on one charge of granular resistor material.

The furnace operates on either alternating or direct current up to 125 volts and the size of heating chamber is $2\frac{1}{4}$ in. diameter and $3\frac{3}{4}$ in. deep. All refractory parts are replaceable.

A Special Cut-Out

In localities where the atmosphere is highly charged with impurities much inconvenience and expense has always been experienced on account of the ordinary porcelain cut-outs protecting pole-type transformers blowing unexpectedly for no apparent reason. Investigation has shown that the porcelain type of cut-out cannot be prevented from absorbing a certain amount

former banks supplying by-product plants, steel mills, furnaces, etc., where the deleterious influences are particularly severe, with entire success. The S & H oil immersed cut-out is similar in principle to the high-capacity cut-out of this firm, with the addition that the whole unit is completely immersed in oil contained in a non-corroding metallic case. The cut-out has a rating of 250 amp. at 2400 volts, which is capable of handling the largest distributing transformer yet built. This cut-out is absolutely immune from the chemical influences in the air in the open or underground, and gives reliable protection with the maximum of simplicity and the minimum of expense in first cost and upkeep. It has the reliability and ruggedness of the circuit breaker at a fraction of the price.

Fifth Annual Report, Director of the Bureau of Mines

The report of the Director of the United States Bureau of Mines for the fiscal year ended June 30, 1915, contains a résumé of the work of the several departments of the bureau and sets forth the needs for the extension of the work.

In the division of mineral technology the principal investigations have related to the treatment of ores containing uranium, vanadium and radium, tungsten, platinum, thorium and mesothorium, molybdenum. Non-ferrous alloys received considerable attention, and the clay industry was the subject of some investigations.

The metallurgical division continued its investigations of smelter smoke and certain metallurgical processes relating to the recovery of sulphur from ores. The hydrometallurgy of gold and silver ores was carried on through co-operation with the Nevada Mine Owners' Association. The standardization of cyanide tests was begun. The treatment of low-grade complex sulphide ores was investigated in conjunction with the University of Utah. The smelting of titaniferous iron ores was the subject of investigation at Port Henry, N. Y. The zinc and lead ores of Kansas, Missouri, Illinois and Wisconsin were studied with special reference to losses in milling and smelting.

In the petroleum division the principal work was done on the cracking of petroleum and the conservation of natural gas.

The general research laboratory studied the methods of sampling and assaying ores and metals.

Non-Ferrous Metal Market

Jan. 26.—Price changes have been small during the last two weeks, but for the most part have shown an advancing tendency; in fact, practically all of the metals have advanced since our last report. Producers all seem to be in a very strong position and periods of dullness have no effect whatever on the market. There are those who still think the market is resting on a false bottom, but the refusal of the producers to sell or quote early deliveries even to their best friends in some cases seems to repudiate this supposition.

Copper.—The situation in this metal is without precedent, and January and February deliveries are hard to get. The market is strong and 25 to $25\frac{1}{2}$ cents is asked for electrolytic and Lake. Buyers are scared and sellers are shy. Shipping facilities were badly tied up in New England about Jan. 17, and whether they are better now or not cannot be stated. The strike in Arizona was ended on Jan. 24, and early in February normal conditions should be resumed.

Tin.—Aside from a little excitement on Jan. 15,



CUT-OUT

of volatile matter and condensation from the air. In many cases this condensation is of a virulent nature and in short time the metallic fuse element corrodes to such an extent that its current-carrying capacity is reduced until the fuse blows far below its normal rating. The result is that one or whole installations of motors are shut down inadvertently, always at considerable inconvenience and frequently heavy expense for damaged product and reduced output. This matter has become

of such importance in some localities where atmospheric conditions are particularly unfavorable that the transformers have been housed indoors, necessitating additional cost for the building as well as the occupation of space; in other instances circuit breakers have been installed on the poles for the sole purpose of obviating the corrosion of the fuse by chemicals in the air.

For several years the Chemelectric Company, 4327 Kenmore Avenue, Chicago, have been installing their S & H oil immersed cut-out for the protection of some very large trans-



CUT-OUT

when no cable advices were received from London, the market has been somewhat dull and featureless. Prices have remained firm, however, with a slight rise in the last few days so that Straits tin is now quoted at 42.25. Imports are fairly good so far this month.

Lead.—In spite of an apparently dull market the Trust price was advanced to 6.10 on Jan. 21. This is the continuation of a steady advance started last September. It is understood that some large bids at 6.05 have been refused, and it is evident that lead is in a strong position.

Spelter.—Early deliveries have been in very good demand and the market has been strong with prices considerably higher. January, February and March deliveries are much sought for. Current prices quoted range from 19.00 to 19.30 at New York.

Other Metals.—Aluminium has remained dull with prices quoted at 53.00-55.00. Antimony has met with better demand during the last week, and American, Chinese and Japanese brands are quoted at 42.50-43.00. Platinum prices are still entirely nominal at \$88 to \$100 per ounce. Silver is quoted at 57½, a new high for the movement, and quicksilver doesn't know where to stop, being quoted at \$275 per flask.

The Iron and Steel Market

Developments in January served to differentiate the steel market movement from its predecessors. It seems certainly more than a coincidence that the three great market movements of the past dozen years met their ends at the year-end. In 1907, 1910 and 1913, years following periods of heavy buying, the mills ran chiefly on their accumulations of orders. The high points in the unfilled obligations reported by the United States Steel Corporation fell on Dec. 31 of 1906, 1909 and 1912 respectively. A reasonable explanation of the phenomenon is that perforce the market experiences a lull at the holidays and unless it has an exceptionally strong undertone it fails to recover its gait. There were no heavy price advances in 1907, 1910 or 1913, though advances had continued almost to the opening of those years.

The difference this year is that in January steel prices have risen at practically the same rate as in the three months preceding. Four of the most important groups of finished steel products, bars, plates, shapes and tubular goods, experienced two advances in January, while tin plates and wire products each experienced one advance. While black sheets did not advance there was an advance in blue annealed sheets.

Strictly new buying of steel products is in general at a greatly reduced rate. The large business transacted may be regarded as of a routine character. There is very heavy specifying against current contracts, nearly all of which are at much lower prices than now quoted. There is a fair volume of contracting for bars, plates and shapes for third quarter, representing merely the fact that mills have now opened their books, in conservative fashion, for that period. The buyers would have placed their contracts earlier if permitted. There is heavy buying of war material, the tonnage running chiefly into large rounds for shells, but this business in general represents buying for second half shipment, following contracts placed long ago for first half. The production of war material promises to be at a substantially unchanged rate.

As the mills entered the year with a very large volume of specifications, averaging throughout the industry about the equivalent of three months of full production, there is no occasion for much concern as to the ability to operate throughout the year up to the physical limits. The buyers who have furnished the specifications now in hand are, as a rule, ready to furnish additional speci-

fications faster than they can be filled. While strictly new buying is light there is always some new business coming up that will be placed irrespective of the fact that prices are relatively high.

The problem of the steel mill this year is really not one of markets or of sales, but of production and transport. Labor is scarce, despite the general wage advance of about 13 per cent effective Feb. 1, and is likely to grow scarcer, both because immigration is practically shut off and because when spring opens outdoor work will make some drain upon inside operations. The question of transportation has grown more serious. Until very recently the shipment of steel from mills was interfered with only as to destination. New England was embargoed, and little steel was accepted for shipment East for export. The mill output could, however, be shipped elsewhere. Cars have been growing scarce in the past fortnight, and a number of mills have accumulated steel awaiting shipment. In the week beginning Jan. 17 the car supply in the Connellsville coke region averaged about 50 per cent of requirements, curtailing shipments by that amount and the movement of coke in transit became less rapid, so that coke receipts at blast furnaces were greatly reduced. Many had slight accumulations, but many furnaces had to be slowed down. The more heroic operation of banking did not have to be resorted to except perhaps in rare instances, but the country's pig-iron output for the month was probably reduced several per cent. Strenuous efforts made by the railroads resulted in an almost normal supply of coke cars the following week.

The Steel Corporation directors at their meeting Jan. 25 declared a dividend of 1¼ per cent on the common stock, thus restoring the old rate. As the earnings for the December quarter were \$51,300,000, the dividend, amounting to less than \$6,400,000, absorbed less than one-fourth the earnings left after the regular charges, including preferred dividend, were met. Wall Street, however, had been in some doubt whether a dividend would be declared. Inasmuch as the major portion of the advances in the steel market have occurred since Oct. 1, the shipments during the December quarter were at relatively low prices. Excluding standard steel rails, the price of which has not changed for many years, the shipments in the December quarter may be estimated to have been invoiced at about \$12 a ton below the prices now ruling in the open market for shipment at mill convenience. As the shipments in the quarter were about 3,750,000 tons, the average profit per ton, after making an allowance from the reported earnings for profits in ore transportation, was slightly in excess of \$13. The possibilities of earnings in future are therefore astonishing. Production costs are necessarily rising from a variety of influences, one of the more important of many being the general wage advance averaging perhaps 13 per cent which is being made, and which becomes effective in most instances on Feb. 1.

Pig Iron

The pig-iron market has shown no more activity in the second half of January than in the first half. Most observers regard the quietness as phenomenal in the circumstances. The psychology of the situation seems to be that the extremely strong steel market caused pig-iron consumers to cover liberally in recent months, while at the same time it encouraged furnaces to advance prices sharply, producing a price level at which buyers hesitate to make further commitments when they are well covered for a moderate period. The total advances in pig iron from the low level of the early months of last year is between \$5 and \$6 a ton, and the profits of the best-positioned furnaces as to low-

cost operation would be extremely large if they were shipping their entire current make at the existing market prices. Any further advance in pig iron must occur through an actual and serious scarcity being developed. Evidently the buyers feel it the conservative course to take their chances with the conditions when they show signs of arising. The market has been practically stationary for a month. We quote: No. 2 foundry iron, delivered Philadelphia, \$19.75 to \$20.25; f.o.b. furnace, Buffalo, \$18 to \$18.50; delivered Cleveland, \$18.80; f.o.b. furnace, Chicago, \$18.50; f.o.b. Birmingham, \$15 to \$15.50; f.o.b. valley furnaces, 95c. higher delivered Pittsburgh: Bessemer, \$21; basic, malleable and forge, \$18 to \$18.50; No. 2 foundry, \$18.50 to \$19.

Steel

The market for soft steel billets and sheet bars is quotable at about \$32 to \$33 for Bessemer and \$35 for open-hearth, f.o.b. maker's mill, Pittsburgh or Youngstown, but the quotations are practically nominal. Regular consumers have contracts at lower prices, and while deliveries are not in all instances fully up to requirements, prices being obtained on ordinary finished steel products do not justify paying prices that would be asked on fresh transactions. Forging billets made to war specifications are bringing usually between \$50 and \$55. A sale of 4000 tons of rods for February and March shipment is reported at \$55, but the market for ordinary deliveries is quoted at \$42 to \$44, though such figures are regarded as largely nominal.

Finished Steel

About Jan. 21 plates were advanced \$3 a ton to 2.00c. and bars and shapes \$1 a ton to 1.90c. Effective Jan. 24 wire products were advanced \$2 a ton, woven wire fencing being advanced three points to 64½ per cent off list. Regular mill prices are given below, f.o.b. Pittsburgh, unless otherwise noted, and are for delivery at mill convenience, higher prices ruling for early shipment of some products, particularly bars, plates and blue annealed sheets.

Rails, standard sections, 1.25c. for Bessemer, 1.34c. for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 2.00c.

Shapes, 1.90c.

Steel bars and bands, 1.90c., base; steel hoops, 2.10c., base.

Iron bars, Philadelphia, 2.259c. to 2.359c.; Chicago, 1.75c. to 1.80c.; refined iron bars, Pittsburgh, 2.00c. to 2.10c.

Plain wire, 2.05c., base; galvanized wire, 1.75c.; wire nails, \$2.20 per keg, base; painted barb wire, 2.35c.; galvanized barb wire, 3.05c.

Sheets, blue annealed, 10-gage, 2.65c. for Bessemer, 2.75c. for open-hearth; black, 28-gage, 2.60c. for Bessemer, 2.60c. to 2.70c. for open-hearth; galvanized, 28-gage, 4.75c. to 5.00c.; painted corrugated, 28-gage, 2.80c.; galvanized corrugated, 28-gage, 4.80c. to 5.05c.

Tin plate, \$3.75 for 100-lb. cokes.

Steel pipe, ¾ to 3-in., black, 76 per cent off list; galvanized, 60½ per cent off list.

Boiler tubes (less than carloads), 3½ to 4½-in., 64 per cent off list.

Structural rivets, 2.60c.; boiler rivets, 2.70c.; cold-rolled shafting, 45 per cent off list; cold-rolled strip steel, 3.75c. to 4.00c., base.

Titanium Production in 1915.—During 1915 the American Rutile Co. produced 250 tons of rutile worth between \$25,000 and \$30,000 at its plant at Roseland, Va., according to the Geological Survey. This is the largest production to date.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Aqueous Bath Apparatus

(Continued)

512,417, Jan. 9, 1894, Charles N. Waite of Newton, Mass.

Relates to an insulated joint between sections of a metallic conduit, generally a lead pipe, for conducting chlorin gas from the anode compartment of an electrolytic cell. One end of a conduit section is enlarged to a cup-shaped receptacle for the end of another section of the conduit; within the cup-shaped receptacle and surrounding the inner pipe-end is an asbestos washer, and above the asbestos washer is poured melted Trinidad asphalt or other suitable cement not affected by chlorin.

512,970, Jan. 16, 1894, John P. Johanson of New York, N. Y.

Relates to an electric washing apparatus, which is said to aid in the cleaning of soiled clothing during the operation of washing. It consists of a pair of electrodes connected by a flexible conductor to a source of low voltage current; the electrodes are provided with insulated handles and hooks, by means of which they are hung from the edge of the ordinary metal wash-boiler in which they are suspended during the boiling of the clothes in soapy water.

522,619, July 10, 1894, Isaiah L. Roberts of Brooklyn, N. Y.

Relates to an electrolytic-decomposition tank made of iron or like metal, that may serve as the cathode. The anode consists of a carbon rod placed within a bag of pulverized anthracite coal, the coal serving as a diaphragm. The anode may when desired consist of other material than carbon, and the coal dust diaphragm may be retained by other means than by a bag. In practice, a large iron tank is used with a plurality of anodes; the tank is subdivided into small units by placing upright pieces of angle iron, so as to produce separate cells for each anode, the joints between the several angle irons being loose, thereby enabling a circulation of the electrolyte.

523,099, July 17, 1894, Clarence M. Barber of Cleveland, Ohio.

Relates to an apparatus for electroplating a large number of separate articles, such as are light carbons, and consists of an endless conveyor, such as a pair of sprocket chains connected together by parallel links or bars so as to produce a unitary conveyor. Each of the parallel connecting links carries a clamp to support an article to be electroplated, automatic means being provided to fill and empty the clamps, and to immerse and remove the articles into and from the plating vats. The patent should be consulted for details.

550,812, Dec. 3, 1895, Elbert R. Allen of Wallingford, Conn., assignor to Simpson, Hall, Miller & Co. of same place.

Relates to a holder to support spoons, forks, etc., to receive an additional deposit upon the surfaces which are subjected to the most wear. The support consists of a long horizontal clamp made of superimposed clamping bars, the support mounted at its ends upon two upright rocking arms, which enables the tilting of the article to be plated, as a spoon, which is ordinarily clamped at the center, either to one side or the other, to vary the surface immersed.

553,732, Jan. 28, 1896, James H. George of New York, N. Y.

Relates to baths or tanks for electroplating such surfaces as the sides of the hull of a ship. The bath or tank is trough-shaped, and consists of a more or less flexible material such as papier-maché. The tank has broad, flange-like, concave edges, and is held against the side of a ship by suitable shore-pieces; the air is then exhausted from the tank by an air pump which maintains the exhaustion as long as the tank is in use. Suitable electrolytes are allowed to flow into the tank after it is in place, through one or more openings controlled by valves. The patent contains a reference to U. S. patent 498,707.

556,854, March 24, 1896, John Leith of St. Helen's, England, assignor to the Electrochemical Company, Limited, of same place.

Relates to conductors for supplying current to a number of electrolytic cells, or units of current consumption. The conductor consists of a cable made of a plurality of separate insulated wires, each wire supplying the anodes of one vat or cell, a duplicate cable supplying the cathodes of each cell, there being as many separate insulated wires to a cable as there are cells or units. With a long row of cells, the diameter of the cable will diminish from the first to the last, due to the reduced number of wires in the cable as the distance increases, thereby effecting an economy in copper over the practice of using a conductor of the same diameter along the row of cells.

563,972, July 14, 1896, Rudolf Kroseberg and Eugen Straub of Berlin, Germany, assignors to said Kroseberg.

Relates to electrolytic cells in which hollow electrodes are used. The hollow electrode may constitute a cell in that it consists of an anode and a cathode secured to the sides of an annular insulating member, the latter provided with an inlet and outlet for electrolyte. Several of such complete hollow cells are placed in a larger cell containing a liquid maintained at a desired temperature, thus assuring electrolysis under desired conditions. The patent also states that a liquid of any desired temperature may be caused to circulate through the hollow cells, and electrolysis takes place in the outer larger cell.

565,953, Aug. 18, 1896, Emile Andreoli of London, England.

Relates to an apparatus in which is carried out a process of so-called indirect electrolysis. The apparatus consists of a three-compartment cell, containing two porous diaphragms. The outer compartments constitute anode and cathode compartments, the inner compartment contains the electrolyte to be subjected to the indirect electrolysis. The apparatus may be used for preparing hydrosulphite of sodium as follows: In the anode compartment is placed a caustic potash (probably caustic soda) solution, and in the negative compartment a sodium chloride solution. In the central compartment is placed a solution of bisulphite of sodium, and immersed therein, but unconnected to the electric circuit, are immersed pieces of zinc in the form of gauze, perforated sheets, etc. During the passage of the current, the indirect electrolysis reduces the sodium bisulphite to sodium hydrosulphite. The sodium bisulphite solution may continuously circulate through several such tanks, and then through a bleaching tank, then through the electric cells. The apparatus may also be used to deposit gold and silver from their solutions, in which case the pieces of metal in the central compartment may contact with a layer of mercury at the bottom to maintain an amalgamated surface.

565,975, Aug. 18, 1896, James H. George of New York, N. Y.

Relates to apparatus for electroplating the sides of

vessels, and contains a reference to U. S. patent 498,707, and to a co-pending application Serial No. 527,916. The present patent relates to a system of supply and drain pipes to circulate the electrolyte to detachable vats temporarily secured on the sides of the vessel. The pipe system constitutes a closed circulating system in which the electrolyte passes through several detachable vats, and through a tank which maintains the electrolyte at the proper strength.

Personal

Mr. D. B. W. Alexander has changed his address from the General Petroleum Co., Los Angeles, Cal., to the Barber Asphalt Paving Co., Maurer, N. J.

Mr. William Bjorkstedt has resigned his position with the electric furnace department of the Siemens & Halske Co., and has accepted the position of works manager of the Stavanger Electro-Staalverk in Stavanger, Norway.

Mr. P. A. Boeck of the Kieselguhr Company of America delivered an illustrated lecture on "High Temperature Insulation" before the Chicago Section of the American Society of Mechanical Engineers on Jan. 14.

Dr. F. G. Cottrell has been appointed chief metallurgist of the U. S. Bureau of Mines and will be located at Washington, D. C.

Dr. Saul Dushman of the General Electric Co. Research Laboratory and formerly of the Chemical Department of Toronto University, presented recently an illustrated lecture on "Electrons, Atoms and Energy Quanta," before the Niagara Falls Section of the American Electrochemical Society. This was followed by a review of the papers given in the past year, in which the entire section participated. The annual election was held at the same meeting and the same officers re-elected.

Mr. H. A. Guess has returned to New York after an extended trip to Chile, during which he visited the Braden and Chuquicamata properties.

The Colorado section of the A. I. M. E. elected the following officers at the annual meeting, Jan. 7: Chairman, L. P. Hammond; vice-chairman, F. H. Bostwick; secretary-treasurer, P. M. McHugh; directors, G. A. Kennedy and M. S. MacCarthy.

The marriage is announced of Mr. A. M. McAfee of the Gulf Refining Company, of Port Arthur, Tex., to Miss Marguerite Avelette Calfee, of Uvalde, Tex., on Jan. 11, 1916. Mr. McAfee is probably best known through his aluminum chloride process for the production of gasoline from high-boiling petroleum oils. A paper by him on this subject was published in our issue of Sept. 15, 1915.

Mr. Clarence W. Marsh, well known through his twelve years' connection with the Development & Funding Co. and the Hooker Electrochemical Co., as chief engineer and special investigator and a director, has opened offices as an independent consulting and chemical engineer at 201 Devonshire Street, Boston, Mass.

Dr. John A. Mathews, president of the Halcomb Steel Co. of Syracuse, N. Y., lectured on Jan. 14 before the Chicago Section of the American Institute of Mining Engineers on "Iron in Antiquity and To-day." The address was illustrated with numerous lantern slides made from historic cuts and illustrations from Dr. Mathews' private library, which contains many rare and old volumes, the oldest dating back to the year 1540.

Mr. Carl A. Nowak has changed his address from Manitowoc, Wis., to St. Louis, Mo., where he will be located at 207 Railway Exchange Building.

The newly elected officers of the Colorado Scientific Society are: **H. C. Parmelee**, president; **T. B. Stearns**, first vice-president; **F. E. Shepard**, second vice-president; **A. J. Hoskin**, secretary; **J. W. Richards**, treasurer; **S. A. Ionides** and **V. G. Hills**, members of the executive committee.

Mr. F. E. Pierce presented a paper on "The Zinc Smelter of To-day" before the annual meeting of the metallurgical and mining section of the Engineers' Society of Western Pennsylvania on Jan. 25.

Mr. R. E. H. Pomeroy, superintendent of the Steptoe smelter of the Nevada Cons. Copper Co., has been visiting at Anaconda and Great Falls.

Mr. John H. Rickard is superintendent of the anti-monopoly smelter near San Francisco.

Mr. J. M. Mitchell Roberts, metallurgist for the Seoul Mining Co., Korea, is on a visit in California.

Obituary

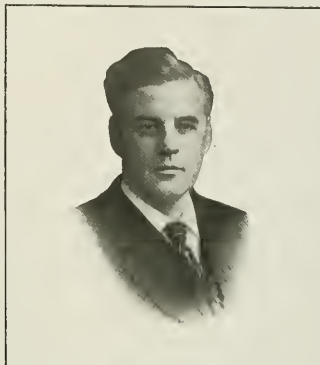
Florentine J. Machalske, an electrochemist, died at Plattsburgh, N. Y., on Jan. 16. Since November 1912 he had been experimenting with a new electric-furnace process for manufacturing steel.

B. E. Sperry, president of D. R. Sperry & Co., Batavia, Ill., died on Jan. 5, after an illness of about three weeks. He was sixty-three years of age and had been associated with his company since his eighteenth year. He filled the position of president for nearly a quarter of a century, and during that time the company's business greatly increased. He was the original inventor and designer of the well-known Sperry filter-press, the Sperry patent filter plate and the switch cock and double gutter system of filtration. Another of his inventions consists of the Sperry swing kettle vacuum pan, an ingenious and convenient type of machine found in many branches of the chemical industry. Due to his efforts a complete line of caldrons suitable for farm and industrial uses was developed. He was born in Malone, N. Y., and leaves a widow, five daughters and one son.

William Barker Ruggles, founder and president of the Ruggles-Coles Engineering Company, of New York City, died on Jan. 23 of pneumonia at the age of fifty-four years. He was born at Bath, N. Y., and a graduate of Cornell University. At the time of his death he was president of the Ruggles-Coles Engineering Company, the Novella Cement Company (Guatemala City, C. A.) and the Niagara Cement Company, and a director and the consulting engineer of the Buffalo Cement and Potash Corporation. He was the inventor of the Ruggles-Coles double-shell dryer and of many other engineering devices. He was a member of the American Society of Mechanical Engineers, Engineers' Club, Machinery Club, Cornell University Club and Psi Upsilon Club, and a trustee of Trinity Episcopal Church of Bayonne, N. J., where he had resided for twenty-four years. He had a wide circle of acquaintances among the members of the engineering profession and was highly respected as an able engineer and kind and genial man. He is survived by a widow and one daughter.

John Alexander Hill, president of the Hill Publishing Company, died suddenly from heart disease on Monday morning, Jan. 24, while traveling in his motor car from his residence in East Orange, N. J., to his place of business in New York City, at the age of 57 years. In John Hill one of the two or three great "captains of industry" in modern American technical journalism has gone into eternity—a typical American self-made man. He was an apprentice in a country

printing office at 14, a locomotive engineer on the Denver & Rio Grande at 20, founder and editor of the *Daily Press* of Pueblo, Colo., at 27. His connection with technical journalism dates from the time when as locomotive engineer he contributed stories of the railroads and "Jim Skeevers' Object Lessons" to *Locomotive Engineering*. In 1888 he was called to New York to take charge of this paper and became part owner, but sold his interest in 1896 to purchase the *American Machinist*. In 1902 he bought *Power* and organized the Hill Publishing Company, which has since acquired the *Engineering and Mining Journal*, *Engineering News* and established the *Coal Age*. Mr. Hill is credited with



THE LATE JOHN A. HILL

many achievements in the business of publishing technical journals. A fine monument to his life and work is the Hill Building at Tenth Avenue and Thirty-sixth Street, New York, the home of his papers. Completed in 1914, it is a magnificent structure, equipped with all imaginable mechanical devices—many of his own design—to expedite work and safeguard employees. His ideal of a printing plant was that it should be as dainty and as cleanly as any business office. Accordingly the linotype machines are enameled in white and the composing rooms, the entire engine-room fixtures and the frames of the great presses and binding machines have a similar enamel finish. His life and work has left permanent marks on technical journalism. He was a genial man, fond of companionship and loyal to his friends and to every one of his employees. They placed a tablet to him in his new building still in his lifetime. It reads: "Within this monument to independent truth and service in engineering journalism the employees of the Hill Publishing Company have placed this tablet—an appreciation of the man and employer, John A. Hill."

Industrial Notes

New Utah Acid Plant.—A new sulphuric acid plant to make 100 tons of acid per day is contemplated by the American Smelting & Refining Co. The exact site has not yet been decided upon, but it will likely be somewhere in the Salt Lake Valley.

The Southern Electrochemical Co. will begin operations shortly at its plant in Great Falls, S. C. Nitric acid will be produced from the air by the Pauling process. Power will be derived from the Catawba River. The present output will be about 4 tons of acid per day.

The New Castle Rubber Company, New Castle, Pa., will increase its capital stock from \$500,000 to \$1,000,000 by a vote of the stockholders. Large additions to the plant will be made.

Benzol and Toluol Production.—Production estimates in this new American industry should prove interesting. According to returns to the Geological Survey, the indicated production was 13,942,763 gal. in connection with which there was produced 761,256 lb. of naphthalene. By the end of 1915 there were nineteen new plants in operation recovering benzol and others in the course of erection. Before the war there was but one plant in operation. Some of the plants are not equipped to separate the different oils in the crude, and over 7,000,000 gal. was reported as crude and was shipped to refineries. In the 6,620,093 gal. refined at the place of recovery, there were 4,833,939 gal. of 100 per cent benzol, 1,315,727 gal. of toluol and 470,425 gal. of solvent naphtha. Thirty-one coke-making establishments, with 4993 by-product ovens, contributed to this total, and it is estimated that between 8,000,000 and 9,000,000 tons of coal was carbonized in the ovens. The annual capacity of the benzol-recovery plants now in operation is estimated at over 20,000,000 gal., and with new plants being constructed it will probably reach 22,000,000 gal. This enormous production is much greater than the normal consumption, but it is possible that new uses may be found for it after the war.

Tungsten Production in 1915.—Preliminary returns to the Geological Survey indicate that the production of tungsten ores in 1915 broke the record and that about 2165 tons of concentrates, carrying 60 per cent WO_3 , was produced. This had a value of about \$2,000,000. The largest previous output was in 1910, when 1821 tons was produced. The price in the early part of 1915 went as low as \$5.80 per unit. In the fall unheard prices were reached and up to \$50 and higher per unit was paid for tungsten concentrates. Prospecting did not follow at once as the prices moved so rapidly, but early in the fall considerable prospecting was in progress. Mills were erected by the Primos Chemical Co. at Dragoon and by the National Tungsten Co. at Arivaca, Ariz., to treat the tungsten ores.

Antimony Production in 1915.—According to preliminary figures collected for the Geological Survey, the production of antimony ores in the United States is estimated to have been about 5000 tons, containing 2000 tons of antimony valued at \$325,000. Practically all operations of the past year were new, most were small, and they were widely scattered, so it is difficult to obtain exact figures so soon after the close of the year.

New Uses of Monel Metal.—In our Jan. 15 issue, page 110, in the article under this title mention was made and an illustration shown of a large valve for superheated steam service weighing 3500 lb. made by the Nelson Valve Co., Philadelphia, Pa. This was stated to be a Monel metal valve, but in order to correct any misconception, it should be stated that it is a cast-steel valve, the body having cast Monel seat rings and the bonnet a Monel "pack-when-open" bushing. The valve is of solid wedge type, the wedge being cast in one piece of Monel metal and the stem also made of Monel metal.

The American Blower Co., Detroit, Mich., has sent us its latest edition of Sirocco Service, the little pamphlet devoted to blowers. This pamphlet describes various uses for Sirocco blowers.

The Anaconda Copper Mining Co. has placed an order for six more 10-ft. diameter by 4-ft. cylindrical length Hardinge ball-pebble mills making a total of fifty-six conical mills for its new plant. The Hardinge company reports that the ten mills are direct connected herringbone-gear driven, operating with 75 per cent less power than originally estimated.

At the annual meeting of the stockholders of the American Metal Products Company, Milwaukee, Wis.,

makers of Ampeco bronze, the old board of directors was re-elected as follows: Peter J. Weber, president; Henry E. Berlie, vice-president; Wm. J. Eberle, secretary and treasurer; Richard Gaertner, manager, and Charles E. Helm and August Littmann. Action was taken to secure a larger plant for the increased business of the company.

The Bailey Meter Company has been incorporated under the laws of Massachusetts for the manufacture of recording meters and instruments for power plants and general use. The new company will be in charge of Mr. E. G. Bailey, and will be located at 141 Milk Street, Boston.

Cyanamid Works.—At the end of Mr. W. S. Landis' paper in our issue of Jan. 15 (pages 87 to 90) the place of the American Cyanamid Company was given as Niagara Falls, N. Y., which should read Niagara Falls, Ont., where the company's manufacturing plant is located. The general offices are at 200 Fifth Avenue, New York City, and division sales offices are maintained at Atlanta, Ga., and San Francisco, Cal.

Adjustable-Pressure Centrifugal Pump.—A centrifugal pump has recently been placed on the market by the Karl Kiefer Machine Co., Cincinnati, Ohio, which has a pressure adjusting arrangement by which any pressure may be secured from practically nothing up to 35 lb., depending on the size of the pump. It is intended to be used especially with filters or filling machines where the adjustable pressure is a desirable feature.

The Miller Smelting & Refining Co., Cleveland, Ohio, assayer, smelter and refiner of gold, silver and platinum, announces that it is now located in the Ellastone Building, East Fourth Street and Prospect Avenue. Its old location at 612 Euclid Avenue was burned out.

The Palo Company, New York City, announces its entrance into the laboratory supply and assayer's material business, with headquarters at 90-94 Maiden Lane. It has issued a catalog describing biological, bacteriological, chemical, physical, metallurgical, optical and astronomical apparatus.

The Quigley Furnace & Foundry Co., Springfield, Mass., has awarded a contract for the construction of a new foundry building, 91 x 208 ft.

The Richardson Scale Company, Passaic, N. J., has issued a beautiful illustrated catalog describing its automatic weighing equipment, including the Merrick conveyor weightometers.

The Sarco Company, Inc., has recently been formed by the Sarco Engineering Co. and the Roller-Smith Co. The new company will handle all sales of the Sarco steam traps and temperature regulators, with offices at South Ferry Building, New York City.

Decks for Round-Tables.—In the construction of cement decks for round-tables used in concentrating slime, it has been proposed to mix oil with the cement. A further suggestion is to mix with the cement oxidized linseed oil, after it has been dried and ground according to practice in making linoleum. In the latter industry, boiled linseed oil is allowed to flow in successive layers over vertical sheets of cotton "scrim," each layer being allowed to harden before the next flows on. When a "skin" of $\frac{1}{2}$ -in. thickness is thus formed, the mass is ground for incorporation with resin, kauri gum and ground cork to form linoleum. The addition of linseed oil thus prepared to cement for use on a table deck might improve the surface for collecting and holding mineral.

Magnesite from Greece.—Magnesite may be obtained from Greece without difficulty, according to Commerce Reports, published by the Bureau of Foreign and Domestic Commerce, Washington, D. C.

Metallurgical and Chemical Engineering

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New York Meeting of the American Institute of Mining Engineers

For the past few years the meetings of the American Institute of Mining Engineers have formed a string of grand successes—Great Falls and Butte, Salt Lake City, San Francisco—and in September there will be the Arizona meeting. But in the present week New York City has the privilege of welcoming the mining men from near and far. The outlook for a very profitable and enjoyable meeting is excellent. New York will spare no effort to make its visitors feel at home—and they will find that at present with the new subways in the making, the metropolis at the Hudson is in places nothing more than just a big mining town.

Our Noteworthy Pig Iron Production

The United States is now making more than one-half the world's pig-iron production. While pig-iron production outside the United States is less than before the war, the production of the United States is at a rate 25 per cent greater than the average rate in the record calendar year, 1913. Production of pig iron in the United States compares with the world's production as follows, the figures representing gross tons of 2240 pounds:

	United States	World	United States, Percentage
1850.....	563,755	4,400,000	12.8
1890.....	9,202,703	27,000,000	34.1
1900.....	13,789,242	40,200,000	34.3
1905.....	22,992,380	54,000,000	42.6
1910.....	27,302,567	65,300,000	41.7
1911.....	28,649,547	63,300,000	37.3
1912.....	29,726,937	72,600,000	41.0
1913.....	30,966,152	78,000,000	39.7
1914.....	23,322,244	60,000,000	38.9
1915.....	29,906,000	60,000,000	49.8

The above figures illustrate quite a story. From 1850 to 1890 there was what then appeared to be a tremendous growth in the iron industry, and the United States, then a very new country, naturally witnessed the greatest growth within its own borders. In the decade following there was no lack of either energy or brains in the United States, for there was noteworthy technical progress, but during the major portion of the decade there was an industrial depression in the United States, which prevented the country from doing more than maintaining its proportion of the world's production. Then there began a race between the United States and Germany, the honors going to the United States for several years, but Germany afterwards expanding more rapidly in production, whereby the percentage of the United States was sensibly reduced. The production of the United States in 1913 was very large, but not sufficient to result in as high a percentage as had been reached in 1910 or 1912. The year 1914 comprised seven months of peace and five months of war. The output of the

United States was low throughout the year, from industrial conditions, while the output of the European countries was greatly reduced in the early months of the war, the net result being that production in the United States, while greatly reduced, comprised almost 40 per cent of the world's production, which was so much the worse for the showing the rest of the world made. The proportion of the United States in the first seven months of 1914 was much less than 40 per cent. In 1915 the world outside the United States recovered part of the ground lost, producing iron at a rate considerably in excess of the rate in the early months of the war, but still far below the rate obtaining before the war. The production of the United States in 1915, although 3.5 per cent less than that in the record calendar year, nevertheless comprised practically one-half the world's production, against 43.4 per cent (not shown in the above table) in 1906, the highest proportion previously attained by the United States.

At the present time the United States is still farther in the lead, with production at the rate of 39,000,000 tons. The present rate of production outside the United States cannot be precisely estimated, but it is certainly very much less than 39,000,000 tons. It may not be at much more than 30,000,000 tons, the average rate in 1915, but taking it at 33,000,000 tons, which seems to be rather a high estimate, the proportion of the United States would be 54 per cent, a proportion which nothing but the war, probably, could have brought about. It seems improbable that either during the war or for years afterwards the United States can make a larger proportion of the world's pig iron than it is making at the present moment.

Smelting Bolivian Tin in the United States

The Smelting and electrolytic refining of Bolivian tin ore by the American Smelting & Refining Company at Perth Amboy, N. J., will remove "one of the most remarkable incongruities in the commercial relations of the United States and South America," to quote the Minister from Bolivia to the United States. Bolivia is one of the few countries in the Western Hemisphere that produces tin ore in large quantities. The United States, on the other hand, is the largest consumer of tin in the Western Hemisphere, importing annually from 45,000 to 50,000 tons but producing a negligible quantity. Nevertheless Bolivian tin ore has hitherto gone first to England or Germany for smelting and refining, and then brought to the United States, the latter country paying the cost of European production and transportation. This anomalous condition will now be changed; for the American Smelting & Refining Company has contracted for the delivery of 750 tons of high-grade Bolivian tin ore per month to be smelted at Perth Amboy, and the new plant will gradually be brought to its capacity of 1200 tons per month. The electrolytically refined product will be equal in quality to the best Straits tin.

The economic importance to this country of this change is only realized by a study of the value of Boliv-

ian imports and exports and the small part which the United States has previously played in this business. According to the Department of Commerce, Bolivian imports in 1912 were valued at nearly \$20,000,000, of which the United States supplied only \$1,787,321 worth, as against \$6,423,802 for Germany and \$3,528,041 for the United Kingdom. In the same year the latter nation bought over \$26,000,000 worth of Bolivian exports, while the United States was a buyer to the extent of only \$152,582, or less than one-half of one per cent of the total. With the establishment of a tin smelting industry in this country Bolivia will have a local credit of millions of dollars per annum, and it must inevitably follow that our products will flow to Bolivia in greatly increased quantities.

The Bolivian tin industry was in unsatisfactory condition following the outbreak of war in Europe. Exports fell off and prices declined. The Bolivian government, therefore, welcomes the opportunity for closer commercial relations created by our purchase of one of her principal mineral products. Commercial treaty relations are satisfactory, and no unfavorable tariff is to be adopted by Bolivia that would affect the export of tin to this country. On the whole, the establishment of this tin industry promises to be an entering wedge for wider commercial relations with South America that should be of lasting benefit.

The Chemist and the Banker

In Dr. Baekeland's Perkin Medal address published in our last issue he put forward as an axiom: "Commit your blunders on a small scale and make your successes on a large scale." He then brought out the mental unpreparedness of American bankers to embark in chemical enterprises by the only wholesome and reasonable method of beginning small and growing large, to accord with this maxim.

The reason for this is that our bankers do not know enough chemists and our chemists do not know enough bankers. Of course, the banker is unwilling to risk good money on an experimental lay-out to test some chemical theory that "nobody" can understand. One might as well ask the chemist to invest his savings in cases of hosiery that are said to be a great bargain. He doesn't know the hosiery market and he would be afraid to take the stuff as a gift—and pay storage charges on it. And to any chemical proposition the banker is likely to say: "I don't know anything about chemistry," while his acquaintance with the family doctor is close enough to persuade him that he does know something about medicine and surgery.

Chemists and bankers do not know each other for a social reason. They have not been generally introduced, and when they have met they have not had things to say to one another that were interesting. Now there is no source of information too humble to be worthy the attention of him who seeks knowledge, and in this connection it might do no harm to observe the arts of the social climber who desires to break into society when she moves to town. She may be a very

vapid person, and exceedingly foolish, but she must use her wits to succeed. We have, in this example, the phenomenon of a human animal employing its wits to accomplish the fulfillment of its desires, which is always an interesting one. She lays her plans and makes her arrangements so that, to all appearances by accident, she is introduced to the most influential woman, to the dominant dowager of the temple of fashion. For this occasion she has prepared herself and trained like an athlete. By word or deed or by any of the innumerable wiles of women she engages the interest of the old lady so that the old lady will want to see her again. Following this up she plans her campaign to get more and more acknowledgments of acquaintance until, in time, authority creeps in. Then the dowager had better look out or the climber may climb above her and proceed to rule in her stead.

Far be it from us to suggest that chemists should lure bankers by tea parties and dances and auction or try to do so by spring hats or Chemists' Club coats, or even jewels galore. The instruments must be different, but there is a cousinship in method if they are to succeed. Bankers are on the lookout for investments just as the social dowager is looking for a larger kingdom. The dowager knows there are pitfalls, and that she must beware lest she give credence to persons who will not keep within the social traces. In like manner the banker is frequently lured by promoters anxious to get money into their enterprises, and the bankers' reputations depend upon their ability to steer clear of pitfalls. Now we venture the suggestion that chemists have not trained themselves to display their wares to the critical eye of the banker with the same care and wit that the social climber has availed herself of in breaking into society.

We know something of the wiles of the promoter, but the banker knows them a great deal better. He has juggled with figures and "conservative estimates" of profits anticipated, and prospective balance sheets until the banker has had his fill of that sort of business. He can cast up an imaginary balance sheet himself if he wants to. The attitude of mind that frightens him away most quickly is certainty of success by steps that he cannot understand. What he would like to know is the trade situation, manufacturing costs, the processes that have been already tried out and standardized, and those that are available but which have not been tried out and standardized. Give him this information so that he feels that he knows it and that he can clear up any doubts he may have in his mind to his own satisfaction by further investigation, and he will be as ready to go into chemical ventures as he is to underwrite a street railway enterprise or a mechanical industry. So far he has not been able to satisfy himself. This he must do for conscience' sake, and there are a thousand things that stand in the way of his innocent gaze. There is the tradition that chemical factories explode. Chemicals are poisonous. There is the danger of patent lawsuits. There is the problem of getting the best "formula"—one of the earliest questions that the banker is likely to ask. The formula or prescription theory is

locked very tight in his mind. The problem of opening the banker's mind is often baffling to the wits. So far the American banker has not been able to satisfy himself. The German banker has, and that is the difference—the difference that we have to meet. It is not a question of ability, American bankers are as able as any; it is a question of habit. Bankers all over the world are like the social dowagers (who are often their wives), in that while they may be led, they will not be driven. They are greatly influenced by fashions and styles in investments. It is useless to warn them that they are losing great opportunities. The promoters have worked that plan of persuasion so often that it does not impress them any more.

So, there are the bankers, ready and willing to go into chemical enterprises if only somebody they know and trust can show them the real situation. They do not speak or understand the chemists' language, and they have no chemical affiliations because nobody has set the fashion for it yet. As soon as it becomes known that one or two leading banking houses have as good and competent connections in chemistry as they have in law or in civil engineering, others will be as ambitious to follow the lead as are the women to have their skirts cut short, now that the style calls for it.

The problem, then, is to get this fashion into vogue, and since the bankers must start it, and chemists are not bankers, the method of induction would seem available. For this purpose we suggest that the meetings of banks' and bankers' associations offer the opportunity. Like all of us, bankers are anxious to learn, but they have an idea that information must be imparted to them in a language that they can understand. This idea or prejudice must be respected, otherwise they will close their ears. The committees on arrangements of the meetings of the local, State and national banking associations are eager to secure addresses that will be of interest to those present, and there are hundreds of opportunities every year for men who are enlightened in chemistry to tell them of the possibilities of chemical development within their territory. A few scatter-brained enthusiasts who say more than they know could kill these opportunities for years to come, but a number of the right men, talking to bankers on the occasions when we know that they would be glad to hear them, would do a world of good. The work should be looked upon as pure missionary effort, with no thought of reward for the speaker. In this attitude of mind he has but two rules to heed: That he draw no pictures that cannot be realized unto success under good management, and that he go through his address with a fine tooth comb and clean out every technical expression that he can. The man of books and ledgers and bills of exchange and warehouse receipts must be made as familiar with every term used as he probably is with kilowatt-hours and surely is with bales of cotton or tons of hay. He will not object if the speaker explains something that he already knows; he will like it; it will prove that the speaker is sound in knowledge and understanding. It is no insult to any audience to speak in words of one syllable.

Reader's Views and Comments

Hydrometallurgy of Zinc and Lead

Electrolytic Zinc

To the Editor of Metallurgical & Chemical Engineering:

Sir: Replying to the discussion by Mr. C. A. Hansen of our article on the hydrometallurgy of zinc and lead in 1915, we are gratified that our contribution was the means of bringing out definite data on such an important subject.

As to Mr. Hansen's statement that we were slightly inaccurate in attributing to him the use of only the "hydrate" process, at the time of writing our paper we were in possession of data on his more recent work, but as it had been given to us confidentially, we did not feel at liberty to mention it.

As regards the hydrate process in general, the idea of neutralizing the acid generated during electrolysis by some device or other was probably introduced into the United States some years ago by Carl Hering. Hering's patents were taken up by a California concern and the production of electrolytic zinc has been experimented on for many years in California. Most of the work done in that State was based upon the belief that the acid generated during the electrolysis must be neutralized, and consequently the ideas developed in connection with that work have shown great ingenuity in the different methods by which this object could be accomplished. For this reason we stated that we regarded the electrolytic work which has been done in Ontario as being very similar to that which has been done in California, and especially at Bully Hill. However, this is no reflection on the work which has been done there, as we believe that the work of Mr. Hansen and his associates has been a most important contribution to the commercial production of electrolytic zinc.

We note Mr. Hansen objects to our statement that an electrolytic zinc plant is not a poor man's proposition, and offers as evidence that we are in error regarding his estimated cost of a plant for reducing 200 tons of spelter per day from the Butte and Superior concentrates as being \$2,400,000. His estimate is doubtless very close to what the actual cost would be, and it was just this fact upon which we based our own conclusions. Perhaps it would have been better had we stated that the cost of an electrolytic plant is about the same as that of a retort plant for the same capacity. However, there are few companies in this country which can afford the outlay for an electrolytic plant. Hence our statement that such a plant is not a poor man's proposition, and our belief that at the present time the electrolytic zinc process is not well adapted to the production of zinc by small companies who wish to work the ores from small low-grade deposits, or even small high-grade deposits. An electrolytic plant calls for large deposits of favorable ore, and a steady production.

We believe that Mr. Hansen's communication constitutes a very important contribution to the literature of the subject of electrolytic zinc.

DORSEY A. LYON.

Salt Lake City, Utah.

Electrolytic Lead

To the Editor of Metallurgical & Chemical Engineering:

SIR:—Replying to the communication from Mr. Henry R. Ellis regarding what we had to say as to the hydrometallurgy of lead, we note Mr. Ellis claims to having had a prior knowledge of the facts underlying the brine process. We had not intended to give the

impression in our paper that we were presenting new facts unknown to previous writers, but rather that we had worked out a new process, based on facts worked out in three semi-commercial plants and in our own laboratories.

As a matter of fact, Mr. Ellis in his turn was not the original discoverer of the fact that lead can be extracted from its ores by the use of a strong brine. Several months ago in looking up the literature on this subject we found that in 1854 M. M. Bequerel of Paris had carried on experiments based upon the above facts. His work was reported in *Comptes rendus* (1854), 38:1095, and also in *Dingler's Polyt. Jour.* (1854), 133:213. Bequerel treated over 20,000 lb. of ore from Mexican and South American mines, as well as small lots of ore from the Erzgebirge, the Altai Mountains, and from different localities in France. He gave these ores a sulphatizing roast in the presence of salt, then leached out lead sulphate and silver chloride with a saturated brine. The brine was electrolyzed to recover the metals. This proposal of Bequerel's is almost identical with our present proposal, with the exception that modern commercial conditions are different from those existing at the time of Bequerel. As a source of electric current Bequerel only had primary cells, and it was doubtless the high cost of this item which caused his work to be dropped.

The process described by Mr. Ellis is different from the process mentioned by us in that he does not use a saturated solution of salt. We have found that the solubility of lead compounds falls off very materially as the solution is diluted, so that a half saturated solution has only 1/7 of the dissolving power of the saturated solution. Mr. Ellis, however, used hot solutions, which are capable of dissolving more lead than cold solutions, but we prefer the use of a cold saturated brine, which we feel is much closer to being commercially practicable.

DORSEY A. LYON.

Salt Lake City, Utah.

Hydrometallurgy of Lead

To the Editor of Metallurgical & Chemical Engineering:

SIR: Your correspondent Henry R. Ellis is the author of a statement in your issue for Feb. 1 that lead sulphate was extracted with brine in 1892. It is known that the process was employed earlier than that, as an English patent (No. 2316) was granted to a Mr. Wright in 1869 for identically the same operation, and it is not a long guess that a thorough search would reveal references to it in Pliny and Agricola.

There were two features in the work referred to by Lyon, Ralston & Cullen in your issue for Jan. 1, which apparently have escaped the observation of experimenters during the last fifty years. A diligent search has so far failed to discover any reference to them and there is accordingly still room for hope that they may have the element of novelty—but that is another story.

S. A. IONIDES.

Denver, Colo.

More Newspaper Science

To the Editor of Metallurgical & Chemical Engineering:

SIR:—The accompanying literary and scientific gem, clipped from a Western newspaper, sheds new light on copper hydrometallurgy as practiced by the energetic

and enterprising reporter. Speaking in detail of a certain process, he says:

"The insoluble compounds in the solution, such as oxides, come over in the stream of electrolysis and are deposited on the cathode plate in the form of pure copper and traces of other metals that may be present."

Thus another triumph is scored for electrometallurgy, and the gaiety of metallurgists proportionately increased. We are left in the dark, however, as to just how this "stream of electrolysis" is measured or controlled. How unfortunate that "pure copper" thus produced should be contaminated with "traces of other metals that may be present!" Something should be done to overcome this slight defect, and the point is brought to the attention of your readers in the hope that so valuable a process may shortly be perfected.

Denver, Col.

H. C. P.

Western Metallurgical and Chemical Field Pacific Coast Enters Electrochemical Field

The State of California is shortly to have a new industry.

The Great Western Electrochemical Company has recently been organized and incorporated in the State of California, for the purpose of manufacturing electrochemical products.

The first operation will be an electrolytic caustic soda plant in which caustic soda and chlorine products will be manufactured. The Moore Allan cell will be used, and bleach chambers such as used at the Dow Chemical Co. will be installed.

The future plans for this company are still somewhat indefinite, but it can be stated with certainty that other electrolytic products as well as electric-furnace products will be manufactured.

Ground is already broken for the new factory and the buildings and equipping of same is in charge of the Foundation Company of New York.

The location of the factory in Pittsburgh, Cal., 50 miles from San Francisco, is a very favorable one. The site, comprising some 40 acres, faces on the San Joaquin river which is navigable at this point by sea going vessels. In addition, service by the Southern Pacific and Santa Fe railroads is obtained.

The power supply is furnished by the Great Western Power Company, whose main transmission line passes in the close vicinity of the factory site.

The necessary salt and lime will be obtained from local supplies, and the needed fresh water is obtained in abundance in the San Joaquin river.

The plant will be in operation by July, 1916.

Directors of the new company are:

Mr. John F. Bush, formerly General Manager and Vice-President of Hooker Electrochemical Company.

Mr. Franklin Remington, President of The Foundation Company, New York.

Mr. J. W. Beckman, formerly of Niagara Falls, N. Y.

Mr. L. Bowen of Detroit, Mich.

Mr. Mortimer Fleishhacker of San Francisco, President of the new Electrochemical Company.

Mr. Louis Bloch, San Francisco, General Manager and Vice-President of Crown Willamette Paper Company.

Mr. Herbert Fleishhacker, President of Anglo-London Paris National Bank, of San Francisco.

Mr. A. Lilienthal, Secretary of the new corporation.

Mr. C. Hall.

The firm of Bush, Beach & Gent, 80 Maiden Lane, New York, will be the selling agents and will also maintain an office in San Francisco.

Annual Meeting Canadian Mining Institute

The eighteenth annual meeting of the Canadian Mining Institute will be at Ottawa, March 1, 2 and 3, 1916. The headquarters will be at Chateau Laurier Hotel. A symposium of flotation will be given by T. A. Rickard, E. P. Mathewson, Henry E. Wood and H. W. DuBois. Another feature of interest will be a paper on rock-crushing tests at McGill University, by J. W. Bell. The subject of education in mining and metallurgy will also receive attention from several contributors. The annual dinner will held on the evening of March 2, and on other days of the meeting visits will be made to places of technical interest in Ottawa.

Great Falls Electrolytic Zinc Plant

Work on the construction of the electrolytic zinc plant of the Anaconda Copper Mining Co., at Great Falls, Mont., is now in progress and will be completed as rapidly as possible, according to *The Anode*.

This plant will take the concentrates from the concentrator at Anaconda and will produce 100 tons of electrolytic zinc per day. The operations to be performed may be said, briefly, to be as follows: The concentrates are given an oxidizing roast, which renders the zinc and a small amount of other minerals soluble in a sulphuric acid solution. The roasted concentrates are, therefore, leached by such a solution and the impurities are precipitated by adding limestone and zinc dust as necessary. The purified solution is then sent to the electrolytic cells and the zinc is deposited as a sheet on the cathode.

The electrolytic zinc made by this process is much purer than spelter and has certain physical properties which spelter does not possess. Among other things, it is much more ductile and is particularly suited for use in the manufacture of high-grade brass.

Part of the slimes flotation plant building is being equipped with apparatus to treat 200 tons of zinc ore per day by the oil flotation process. The concentrates made in this plant will be treated at the Anaconda experimental zinc plant, which is to be enlarged, and will produce 25 tons of zinc per day.

Plans are now being drawn for a concentrator to treat 2000 tons of zinc ore by the oil flotation process, and it is expected that the plant will be completed by July.

The concentrates from this plant will be sent to Great Falls for treatment at the electrolytic zinc plant at the B. & M. Reduction Works.

Terms of Settlement of Arizona Labor Strike

After four months of idleness, during which time the employees of the Arizona, Detroit and Shannon copper companies lost their wages, and the companies lost the profit from about 6,000,000 lb. of copper per month, the labor strike in the Clifton-Morenci district of Arizona has been settled. The net result is a loss for all concerned, and the terms of settlement finally accepted are such as could have been obtained in the beginning.

The conditions under which work has been resumed are those offered by the managers of the several companies on Jan. 8, and are substantially as follows: The charters of Western Federation of Miners locals in Clifton, Morenci and Metcalf are surrendered in good faith, and the influence of outside agitators is eliminated. The men return to work under the former wage scale, which the managers offer to extend to meet the increased price of copper. It is understood that all workmen employed by the companies will receive full and adequate protection. The managers agree that no individuals of any nationality will be barred from re-employment because of their connection with the strike movement, except those who have been guilty of acts

of violence; and for this latter reason no more than ten will be discriminated against by the three companies.

The managers agree that upon resumption of operations and conditions becoming normal, they will meet committees of their employees with a view to adjusting any grievances or considering any questions which the employees may wish to bring up, the intention of the managers being to make conditions as satisfactory as possible for the employees.

The table below shows the rates of wages received by the principal classes of employees for the period Aug. 15 to Sept. 15, 1915, together with the rates which will be paid to the same classes of labor when the indicated prices for copper prevail.

Occupation	Hours	Wages, with Copper Selling At					
		Per Hour	Per Shift	Per Hour	Per Shift	Per Hour	Per Shift
Miners	7½	\$0.36½	\$2.74	\$0.39½	\$2.96	\$0.45½	\$3.41
Muckers and trimmers	7½	.28½	2.14	.31	2.33	.36	2.70
Timbermen	7½	.38½	2.83	.41	3.08	.47	3.52
Laborers (surface)	8	.24	1.92	.26½	2.12	.31½	2.52
Charge-wheelers	8	.26½	2.12	.28½	2.28	.33½	2.68
Skimmers	8	.44	3.52	.46½	3.72	.51½	4.12
Funchers	8	.33	2.64	.35	2.80	.40	3.20
Laborers	8	.24	1.92	.26½	2.12	.31½	2.52
Carpenters and electricians	8	.54	4.32	.57½	4.60	.62½	5.00
Machinists and boilermakers	8	.57	4.56	.60½	4.84	.66½	5.32

Non-Ferrous Metal Market

Feb. 10.—The metals continue in their strong position. The only decline recorded during the last two weeks was one of about ½c. in tin. The other metals either remained unchanged or registered advances. The extraordinary situation in copper has forced that metal still higher, while most of the other metals are scarce to a greater or less degree for early deliveries.

Copper.—Producers are sold up for several months ahead, in some cases up to July and August and deliveries this side of May or June are hard to obtain. The market has risen steadily since our last report and quotations are now 27 to 28c. for nearby deliveries and 26 to 27c. for June and later deliveries. Conditions abroad are reported to be about the same as ours and a scarcity has forced prices up. Electrolytic is quoted in London at £131 spot. Rumors are afloat of heavy foreign buying for shipment now and after the war. England is said to have bought 100,000 tons and Germany a large amount for later shipment. Whether the present market is due to these purchases is a matter of conjecture, but it is thought by a number of authorities that this is the case. At any rate the domestic consumption is very heavy and articles in which copper is used will naturally be higher priced.

Tin.—Good sales of tin were reported the last few days in January. Early deliveries and futures have not been hard to buy. Stocks on Jan. 31, figured from the deliveries, were 2401 tons. Arrivals in January were 4430 tons. There is no scarcity of tin, either spot or en route. The market during the first ten days in February has been dull. Straits is quoted at 41.25 f.o.b.

Lead.—Up until Feb. 8 lead remained dull. On that day a good demand appeared for both prompt and future deliveries, and lots for sale by outside parties not connected with the Trust are commanding a premium. The Trust price is still 6.10 New York.

Spelter.—Buying of spelter was scarce up to Feb. 8, when large purchases were made. Deliveries up to May are being sold. Second quarter deliveries are quoted at 16.50c. St. Louis, March at 18.50, February at 18.75. Spot spelter is 19c. at St. Louis and 19.17½ to 19.42½ at New York.

Other Metals.—Aluminium advanced 1c. on good in-

quiry and is now quoted 54.00 to 56.00. Antimony was in good demand on Jan. 31, after two weeks' dullness. Supplies are scarce and the quotation is now 43.50 to 44.00, with the market firm. Silver moved up and down within a narrow range and is now quoted at 56½. Platinum is still hard to quote, owing to the scarcity, and \$88 to \$100 per oz. remains the nominal price. Quicksilver is quoted at \$275 to \$300 per flask.

The Iron and Steel Market

The steel market has become distinctly quiet as to strictly new buying, but on the whole there is as heavy specifying as ever on open contracts. In some quarters the slowing down in the rate of new buying is interpreted as suggesting that a change has occurred in the general situation, but the majority view is that the slowing down is due to the physical condition that the market is already sold out.

The future of the mills for the purpose of forecast may be divided into two periods, that for which they have specific orders on books, or orders practically assured, and the later period for which consumptive demand must develop, on the basis of higher prices than have hitherto obtained. With the average mill the first period comprises about six months. Some mills have definite orders and specifications on books for fully six months, while others have such business for a shorter period, with every indication that orders will continue heavy for a time. The great bulk of this specific business is at prices much below those now ruling. There are some specifications yet to be filled that were filed against fourth-quarter contracts, and the contracts now being specified against are as a rule at much lower than current prices, averaging in the case of bars, plates and shapes about 1.45c., while the present market is 2.00c. on bars and shapes and 2.10c. on plates.

It is natural that doubt should be entertained whether consumption will be seriously curtailed in future when buyers must pay the present high prices. It is a question not for nearby months but for the second half of the year, perhaps only for the fourth quarter. The prospect for heavy consumption is made favorable by the fact that the present demand is very well distributed, and appears to be chiefly for the filling of everyday requirements rather than for large construction projects in which costs are carefully considered. It is much more difficult than usual to trace to its ultimate use the steel being shipped. The consumption of standard rails is extremely light and structural tonnage is far from heavy. There is feverish activity among builders of machinery and automobiles, lines of consumption in which price cuts almost no figure. It is interesting to observe that there is but one steel commodity that has not advanced in price, standard steel rails for domestic roads, and it is that commodity which is being produced at the lowest rate. Rails for export have been selling at relatively high prices, and rail exports are at a record rate. In this one instance at least the price has no influence upon the demand.

Exports of iron and steel returned by weight were 363,000 gross tons in November, slightly more than in October, but less than in any of the three months preceding. There is no reason to suppose that the consumption of steel in the manufacture of export products that are not returned by weight has increased from the average of the months of July to November inclusive. In that period the exports that are returned by weight represented a rate of about 4,000,000 tons of finished rolled steel per annum. An estimate

of 3,000,000 tons of finished steel a year would probably be high for that consumed in the manufacture of the indirect exports, including loaded and unloaded shells, machinery, automobiles, railroad rolling stock, etc., so that it does not appear that finished steel made for all export purposes is at a rate higher than about 7,000,000 tons at the outside. The current production is at approximately 29,000,000 tons.

The steel trade is so extremely prosperous at present that interest centers not so much upon the bearing that current events may have on the present or the nearby future as upon the bearing they have upon the course of trade in the more distant future. Obviously the steel mills will be under pressure for more than six months, but whether they will be under pressure for nine months, a year or three years is another matter. Many of the mills are uncomfortably over-sold at present and would require months even of a quiet market to recover. What is probably an important indication for the future is that at the present moment the demand for prompt material, which commands premiums over forward deliveries, is as great as it was 30 days ago and greater than it was 60 days ago. While the large mills do not accept premiums for prompt shipment, the smaller mills make this their rule. In plates, for example, carloads for shipment within a week or two are bought freely at 3.00c., while orders for 100 to 500 tons are common for delivery over 90 days, at about 2.50c., these prices comparing with the regular price of 2.10c. made by large mills for delivery at their convenience.

Pig Iron

The dullness that characterized the pig-iron market in January has since developed into absolute stagnation, with signs in some quarters that prices are perhaps a shade easier, though they are not quotably lower. Pig-iron production by both steel interests and merchant furnaces has increased further, and is now at the rate of about 39,000,000 tons per annum, a rate which a year ago no one thought the furnaces could possibly compass. The question is the one which so often develops in the pig-iron market, which party, the buyers or the sellers, can hold out the longest. We repeat former quotations: No. 2 foundry iron, delivered Philadelphia, \$19.75 to \$20.25; f.o.b. furnaces, Buffalo, \$18 to \$18.50; delivered Cleveland, \$18.80; f.o.b. furnaces, Chicago, \$18.50; f.o.b. Birmingham, \$15; at valley furnaces, 95 cents higher delivered Pittsburgh; Bessemer, \$21; basic, \$18 to \$18.50; No. 2 foundry, \$18.50 to \$19; forge and malleable, \$18 to \$18.50.

Steel

There has been a slight softening in the unfinished steel market, to the extent that odd lots of billets and sheet bars can now occasionally be picked up for fairly prompt shipment, whereas until very recently there was practically no steel to be had except at prohibitive prices. While the market is still not clearly defined, it is probably represented better by \$33 for Bessemer and \$35 for open-hearth billets and sheet bars, f.o.b. maker's mill, Pittsburgh, or Youngstown, than by any other figures. We note sales of three lots of sheet bars aggregating about 1500 tons for prompt shipment on a basis of a trifle under \$35, f.o.b. maker's mill, Pittsburgh, but it is only occasionally that such lots can be picked up. Rods are quotable roundly at \$45, Pittsburgh, but are largely nominal at that figure.

Finished Steel

On Feb. 4 the Carnegie Steel Company advanced its prices on bars, plates, shapes and hoops by \$2 a

ton, the advanced prices readily becoming the general market. For early shipment plates are bringing 2.50c. to 3.00c., bars commanding 2.25c. to 2.50c. Regular mill prices are given below, f.o.b. Pittsburgh, unless otherwise noted, and are for delivery at mill convenience.

Rails, standard sections, 1.25c. for Bessemer, 1.34c. for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 2.10c.

Shapes, 2.00c.

Steel bars and bands, 2.00c., base; steel hoops, 2.20c., base.

Iron bars, Philadelphia, 2.409c.; Chicago, 1.90c.; Pittsburgh, 2.20c. to 2.25c.

Plain wire, 2.05c., base; galvanized wire, \$2.75c.; wire nails, 2.20c. per keg, base; painted barb wire, 2.35c.; galvanized barb wire, 3.05c.

Sheets, blue annealed, 10-gage, 2.65c. for Bessemer, 2.75c. for open-hearth; black, 28 gage, 2.60c. for Bessemer, 2.75c. for open-hearth; galvanized, 28-gage, 4.75c.; painted corrugated, 28-gage, 2.80c.; galvanized corrugated, 28-gage, 4.80c.

Tin plate, \$3.75 to \$4 for 100-lb. cokes.

Steel pipe, $\frac{3}{4}$ to 3-in., black, 76 per cent off list; galvanized, 60½ per cent off list.

Boiler tubes (less than carloads), 3½ to 4½-in. 64 per cent off list; iron, 60 per cent off list.

Structural rivets, 2.70c.; boiler rivets, 2.80c.; cold-rolled shafting, 45 per cent off list; cold-rolled strip steel, 4.00c., base.

The Flotation Conference at the University of Kansas

At the suggestion of Mr. Dorsey A. Lyon, metallurgist for the United States Bureau of Mines, the first gathering of metallurgists and mining men to consider exclusively the rapidly growing subject of flotation came together on Jan. 28 and 29 in the University of Kansas at Lawrence. The Kansas institution was agreed upon as the first meeting place of the conference because of its central location and because of the pioneer work of its Division of State Chemical Research in investigating the application of flotation to zinc recovery within the State.

The underlying object of the conference was to discuss the problems which are yet to be solved in the process of flotation and more particularly to consider the research work now being conducted in various universities and mining schools with the object of encouraging further research and preventing useless duplication among the various investigators concerned.

Among the visitors in attendance at the conference were Messrs. D. A. Lyon and O. C. Ralston of Salt Lake City, representing the United States Bureau of Mines and the University of Utah; Dr. A. L. McKee, director, and Mr. Charles Clayton of Rolla, Mo., representing the Missouri School of Mines; Mr. R. C. Palmer of Madison, Wis., representing the United States Forest Products Laboratory, and Mr. C. A. Wright of the Bureau of Mines, stationed at Joplin, Mo., representing the Joplin Zinc District.

The University of Kansas was represented by Prof. W. A. Whitaker, director of the Division of State Chemical Research, which is prosecuting several flotation investigations; Mr. George Belchic, flotation investigator, and by Messrs. Roy Neal, S. F. Farley and L. E. Van Velzer, assistants in flotation work. Others present from the University of Kansas were Profs. E. H. S. Bailey, C. F. Nelson, A. C. Terrill, H. C. Allen, G. W. Stratton, W. H. Twenhofel, A. H. Sluss and R. L. Crider. Letters were read from more than thirty pro-

fessors of mining and metallurgy throughout the country expressing their approval of such a conference and regretting their inability to attend.

In addition to several informal conferences which were held on the 28th, two regular meetings were held on Saturday, Jan. 29, with Professor Whitaker acting as chairman. The morning session continued from 9.30 a. m. to 12.30 p. m. and the afternoon session from 2 p. m. to 5 p. m. The morning session was consumed by the three following papers and the resulting discussion:

1. "Some Things that May Be Accomplished by a Conference on Flotation," Mr. D. A. Lyon, United States Bureau of Mines.

2. "Proposed Research on Flotation," Dean Milnor Roberts, University of Washington (read by Dr. A. L. McRae). Discussion led by Messrs. Lyon and McRae. In the course of his remarks, Dr. McRae stated that the Missouri School of Mines was engaged in making a complete bibliography on flotation and that this would be completed soon. Mr. Lyon urged the publication of such a bibliography.

3. "The Theories of Flotation," Mr. George Belchic, University of Kansas. Discussion led by Messrs. Ralston and Whitaker.

The discussion on this paper was very full and brought out several new points on theory, especially as regards the relation to flotation of colloid knowledge and surface tension phenomena. The theoretical and practical flotation questions now being investigated at the University of Kansas were reviewed. The discussion was succeeded by three informal talks: Dr. C. F. Nelson of the University of Kansas spoke on colloids; Mr. R. C. Palmer of the United States Forest Products Laboratory spoke of the desire of his laboratory to help in evolving the proper flotation oils as products of wood distillation; Mr. Charles Clayton of the Missouri School of Mines reviewed briefly some of the work which has been done in that institution.

The afternoon session was devoted almost entirely to the formulation of a questionnaire on theory, which, it is intended, shall be sent to all institutions that are engaged in investigating flotation problems. A set of questions was proposed by Mr. O. C. Ralston, and in the general discussion which followed the list was increased by the addition of other questions. At this time, Mr. Roy Neal of the University of Kansas gave some of the data which he had obtained in his experiments on surface tension and interfacial tension. The closing feature of the conference was a talk by Prof. A. C. Terrill of the University of Kansas on "Some Observations on Flotation Practice." Following this talk the conference went into executive session for a few minutes and then adjourned.

On Friday evening, Jan. 28, a "smoker" was given in honor of the visitors at the University Club, at which talks were made by Messrs. Lyon, Palmer, McRae and Whitaker.

American Electrochemical Society New York Section

Electrochemical War Materials — Electrolysis of Underground Structures.

For the meeting of Feb. 11, Dr. C. G. Fink, chairman of the New York Section of the American Electrochemical Society, had arranged an unusually interesting, instructive and timely program, in the form of a symposium of papers on electrochemical war supplies. The attendance at the meeting was very good. Limitations of time and space force us to reserve the full report of this meeting for our next issue. The paper by Dr. G.

Ornstein on electrolytic chlorine presented in this symposium is published in full on page 215 of this issue.

For the evening of March 10, 1916, the American Institute of Electrical Engineers has extended a courteous invitation to the New York Section of the American Electrochemical Society for a joint meeting in the United Engineering Societies Building. The subject of discussion will be electrolytic corrosion of underground structures.

Necessity for an American Dye-Stuff Industry

At the third National Foreign Trade Convention held at New Orleans, La., from Jan. 27 to 29, Mr. HENRY HOWARD, vice-president of the Merrimac Chemical Company, and chairman of the executive committee of the Manufacturing Chemists' Association of the United States presented an interesting paper on "The Necessity of an American Dyestuff Industry to Aid Export Trade in Textiles."

The speaker pointed out that the stoppage of importation of dyes from Germany "has been disastrous to what we all desire—namely: an increase in our foreign trade in textiles. Many textile mills have been obliged to curtail their output at a time when, if we had been independent of other countries, with a dye industry well established, these same mills could have been running night and day manufacturing goods for export and establishing foreign connections by aid of which a considerable percentage of this business might have been retained after the close of the war."

The speaker stated that the fact that there is no adequate coal tar industry in this country can not be charged against the Democratic party but is due "to the strenuous effort of the foreign manufacturers and American importers, ably assisted by the short-sighted selfishness of these same textile manufacturers who are now the principal sufferers."

The speaker pointed out that the American dyestuff industry gave promise in 1882, but then came the fatal tariff reduction in 1883. Now the American textile manufacturers stand ready to co-operate in any way possible in order to establish a permanent coal-tar industry within the United States.

Mr. Howard compared the present condition of textiles in this country with that of iron and steel. "The latter industry, thanks to the consistent protection which for years was extended to every branch of the business, is now absolutely independent of the rest of the world in its ability to manufacture all standard grades of iron and steel products in this country, with the result that not only are all American users of iron and steel products getting their supplies as regularly as before the war began, but a large export business is being developed as the result of the paralysis of this industry abroad. In textiles the saving of a possible 4½ cents on a hundred dollars' worth of product has resulted in so throttling the textile industry that it is having hard work to supply our local markets, much less to gain a strong foothold in the foreign markets formerly supplied by the belligerent countries."

Mr. Howard considers that a permanent non-partisan tariff commission is necessary. Further, unfair competition of foreign dye manufacturers must not be permitted. Finally Mr. Howard pointed out the intimate connection between the manufacture of dyes and explosives. A complete coal-tar dye industry in this country is necessary for the sake of preparedness.

Mr. Howard was not alone in referring to the desirability of an increased export trade. Other speakers emphasized the stabilizing influence which export trade has in any industry.

The Calcination of Zinc Carbonate

BY WILLIAM P. SIMPSON

Calcination in general has been practiced as long as quicklime has been known; it consists simply in the conversion of carbonates into oxides by the application of heat.

In the particular adaptation to zinc carbonate the process involves heating the ore to such a temperature as will drive off carbonic acid without volatilizing zinc, leaving zinc oxide, with its decreased weight per unit of zinc, in place of the original carbonate.

Aside from better market value for ores of higher zinc content, the object of calcination may be one of several, depending upon the locality in which the operations are carried on or upon the subsequent treatment of the ore. In the former case the reduction of transportation cost effected by this form of concentration is the desired end. In the latter it is the lowering of fuel expense, decrease in bulk of material handled or the time element involved in the further working of the ore.

For instance, the first mentioned incentive may be illustrated by the case of calcination in Mexico, to accomplish a saving in freight charge on the long haul to the Oklahoma smelters. Illustration of the latter object may be had in Belgium and Germany, where calcination is employed before retort smelting, thus saving time in distillation, as otherwise a large part of the smelting period would be consumed in driving off CO_2 before distillation of zinc could begin. Further, the smelting of calcined ore would increase the capacity per retort due to the previous concentration of the ore by calcination. Formerly it was considered essential to get rid of CO_2 before retorting carbonate ores. Of late years, however, American smelters have charged crude carbonates into their retorts, proceeding with distillation as when roasted blende is used.

Labor Cost Limits Use of Process.

Factors in the practicability of employing calcination in any given case are the relative cost of labor and fuel. As in the early history of sulphide roasting, so in the calcination of zinc carbonate, hand work has thus far given better results than mechanical treatment. This fact has retarded the use of calcination in this country, where labor is the big item in operating cost, fuel being comparatively cheap. In Europe labor is cheap and fuel expensive; hence at the expense of labor and the saving of fuel, calcination precedes retorting as previously explained, a cheaper grade of coal being used in calcination than for smelting.

The history of calcining zinc carbonate begins with the exploitation of such ore in Algeria, Greece, Italy, Spain and the island of Sardinia. In these countries calcination is practised at the mines. For many years the smelters of Belgium and Germany have employed calcination before retorting. In the United States the only locality where the process is being conducted, as far as I am aware, is at Arden, Nevada, where purely mechanical handling has thus far resulted in very incomplete, but profitable, calcination. For several years Oklahoma smelters have been receiving increasingly large shipments of calcined zinc ore from Mexico, and until the European war broke out Mexico had for ten years shipped calcined ore as ballast to Europe.

Beginning with the chemical or laboratory side of the subject, there is one ore which is of chief importance, viz., smithsonite, ZnCO_3 . The molecular weight of this carbonate is 125.4; that of zinc oxide is 81.4. This gives a ratio of carbonate to oxide of 1:0.649, or roughly 1:0.65. Assuming the zinc in an ore assaying 32.5 per cent to be pure smithsonite, the zinc percentage after calcination will be $32.5 \div 0.65$, or 50 per cent.

Experience, however, shows that this method of determining the zinc content which may be expected from calcining any particular ore is not satisfactory. Several conditions explain why this procedure may not be confirmed in actual practice. First, the ore may not contain its zinc as pure carbonate; second, calcination is rarely complete, and a product is seldom obtained which would be comparable to what is known as a sweet roast in desulphurization, from 0.4 per cent to 1.5 per cent of carbonate often remaining in the best calcine. On the other hand, there are often carbonates other than zinc in the ore, such as calcium carbonate. The decomposition of these may cause a decrease in weight and consequent increase in zinc in the calcine beyond the percentage that would be indicated by this method of calculation.

Laboratory Calcination Assay

The relation of the calculated result to that obtained in actual practice may be determined by a laboratory calcination assay, as follows: Ten grams of the powdered crude ore is weighed into a 3-in. scorifier or saucer-like porcelain dish and spread in as thin a layer as possible. The dish is then placed in the muffle of an assay furnace at such temperature as will bring the ore to a dull red glow in ordinary daylight. The muffle door is left open and the furnace doors are so manipulated as to cause the greatest draft through the muffle and produce the best oxidizing conditions. A little practice and experience based upon comparative tests and assays will enable the assayer to gage the temperature by the eye. Too high a temperature, above 920 deg. C., results in loss of zinc; too low a temperature, below 300 deg. C., or too short a time, will result in incomplete calcination. Two hours in the furnace under proper conditions will give satisfactory results.

At the expiration of this time the assay is removed from the furnace, and when cool it is returned to the scale pan of the balance, with the same ten-gram weight on the opposite pan. Equilibrium is now established

TABLE I

Laboratory calcination assays, showing comparison of different methods of calculating percentage of zinc in the calcine.

No.	Crude Ore, Per Cent Zinc	Calcination Loss, Per Cent	Complement of Calcination Loss	Per Cent Zinc Calculated from Calcina- tion Loss	Per Cent Zinc Assayed by Assay	Per Cent Zinc Ore Was Pure Carbonate (% Zn $\div$ 0.65)
1	16.7	13.7	86.3	19.4	19.1	25.8
2	19.7	14.3	85.7	23.0	22.7	30.2
3	20.8	16.6	83.4	25.0	25.0	31.4
4	21.4	19.0	81.0	26.5	26.2	33.0
5	22.3	18.3	81.7	28.7	26.7	34.3
6	23.5	21.0	79.0	35.1	36.0	43.8
7	31.3	25.0	75.0	42.5	42.6	49.1
8	33.3	18.9	81.1	41.1	40.5	51.3
9	41.2	24.0	76.0	54.2	53.7	63.5
10	42.4	24.5	75.5	56.2	55.0	65.5

TABLE II

Ideal Charge

Ore Class	Quantity	Class Factor	Resultant
1	20 barrows @	4	80
2	5 barrows @	3	15
3	2 barrows @	2	4
4	1 barrow @	1	1
	28		100

TABLE III

Showing variation limits in charges and their effect on capacity. One barrow-load weighing about 400 lb.

Resultant	Charges of 28 Barrows Each	Capacity Tons
95	3½	20
97	4	..
99	4½	..
101	5	..
103	5½	..
105	6	..
107	6½	36

by adding the necessary small weights to the pan containing the assay, and these weights indicate directly the percentage loss of weight by calcination. This is called the "calcination loss." Now the complement of this calcination loss (80 per cent in the case of 20 per cent loss) divided into the zinc percentage of the crude ore will give a very close approximation to the zinc percentage that may be expected from calcination on a commercial scale. The actual operation in kilns generally results in still greater calcination loss than the assay shows.

Table I contains the results of ten laboratory calcination assays, and shows comparatively the zinc content of the calcine as determined (a) by the method of calcination just given; (b) by actual assay of the calcine; and (c) by calculation on the assumption that the ore is pure carbonate. The first two sets of figures agree quite well and show the reliability of the calcination assay. The third set, on the other hand, show by contrast the misleading results obtained when assuming the zinc to exist as pure carbonate.

In practice, daily samples of crude ore and calcine are assayed for zinc and calcination loss, to control the operation of the furnace or kiln, just as in lead smelting assays of bed samples and slags inform the metallurgist of the operation of his blast furnace.

Three Essentials to Success

Turning now to the practical application of the process, the method and equipment are very simple; yet three points are of such vital importance that calcination has proved a failure in the hands of novices. These three points are: 1—sizing of the ore; 2—form of furnace or kiln; 3—manner of charging.

For calcining in kilns the ore is passed over grizzlies or screens to produce the following four grades:

Class 1: oversize of a 3-in. grizzly; from 3 to 5 in. in diameter, averaging 4 in.

Class 2: undersize of a 3-in. grizzly, remaining on a 1-in., averaging 2 in.

Class 3: undersize of a 1-in. grizzly, remaining on $\frac{1}{2}$ -in. screen, averaging close to 1 in.

Class 4: undersize of $\frac{1}{2}$ -in. screen, averaging about $\frac{1}{4}$ in.

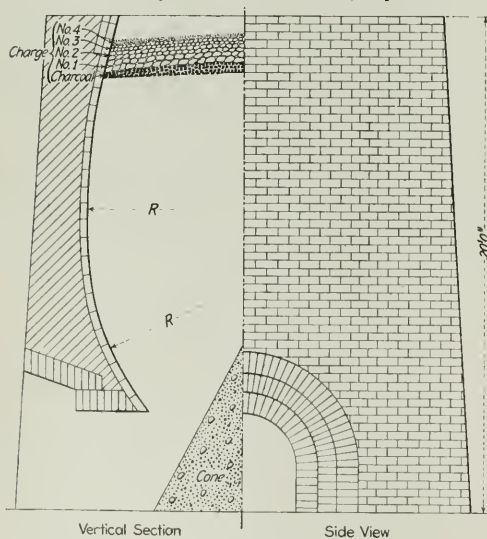
For satisfactory calcination in kilns, experience has

shown the necessity of a certain interior shape or form to permit the charge to descend in uniform horizontal zones and to discharge promptly at the bottom. A vertical section, side view and ground plan of a kiln are shown in Figs. 1, 2 and 3. The exterior is hexagonal in form, about 16 ft. in diameter and 20 ft. high. The feed floor is level with the top. Looking down into the kiln, the interior resembles an ordinary round cistern, though less contracted at the top. The curve of the interior is determined by two radii. It allows for the expansion of the ore in calcining and produces a choking effect at the bottom above the four discharge doors. On the bottom or floor of the kiln is a central concrete cone covered with sheet iron, the apex being at a point above the arches of the four doors. This cone insures an even descent of the kiln contents and a complete removal of the finished product through the four doors.

Method of Charging a Kiln

The initial charging of a kiln consists in building up with wood from the kiln floor to a point above the arches of the doors. The first charge of ore is placed on the wood, consisting of successive layers of the different classes. Class 1 is spread evenly over the wood; then Class 2 is carefully fitted into the interstitial spaces on Class 1 and built up to a layer of desired thickness. Class 3 is superimposed on Class 2, and finally the fine ore, or Class 4, is added, making a level floor of gravel-like structure. Upon this foundation the regular charging begins; first broken charcoal or coal, about 4 per cent of the weight of the ore-charge, followed by layers of ore as above described, beginning with coarse and finishing with fine. In this way zone upon zone of fuel and ore is built up in the furnace, great care being taken in placing the successive layers by hand so as to form porous charges that will ignite readily after combustion is started in the wood at the bottom.

After calcination is started, the product is removed periodically at the bottom of the kiln through the four doors simultaneously, and immediately a new charge is placed in the furnace at the top. The quantity withdrawn at any one time is about equal to the quantity in a charge, and in this way the content of a kiln is kept constant and at a level about one foot below the feed floor. In a kiln 20 ft. high there will be from 8 to 10



FIGS. 1 AND 2—VERTICAL SECTION AND SIDE VIEW

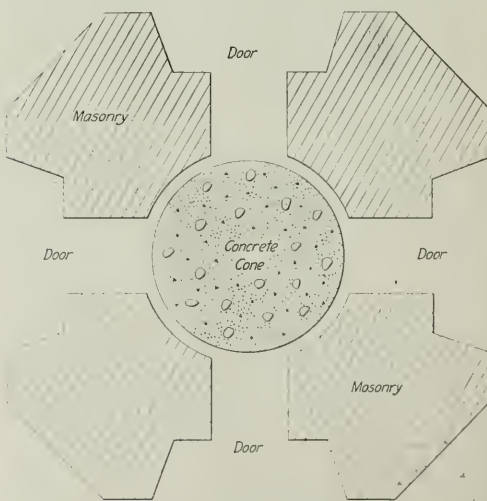


FIG. 3—GROUND PLAN

zones of the type described, each becoming ignited from the one below. Thus, after once blowing in the furnace the process continues indefinitely, the addition of a new charge coinciding with the periodic removal.

Often a kiln will run thus for months much the same as an iron or lead blast-furnace. The heat, however, is not intense, and the men engaged in placing a new charge stand in the top of the kiln without discomfort. Each kiln of the type described has a capacity of from 20 to 36 tons of product per day, depending on the nature of the ore and the proportions of the several classes or grades comprising the charge. A kiln will hold 90 tons of crude and 70 tons of calcined ore. The charges are carefully weighed, and the operation is controlled by the proportion of each class of ore charged.

Empirical Calculation of Charges

The empirical nature of the calcination process as conducted in kilns is illustrated by the method of calculating charges. An ideal charge is given in Table II. This system was developed in the pioneer work with the particular type of kiln above described. Each of the four classes of ore is given a factor in reverse order to its class number. Thus Class 1 has a factor of 4; Class 2 a factor of 3; Class 3 a factor of 2; and Class 4 a factor of 1. The unit of quantity is the wheelbarrow load, about 400 lb. Experience developed the fact that the number of barrow loads of each class could be varied, provided the total number was maintained at 28. As shown in Table II, an ideal charge gives a sum of "results" equal to 100; but the satisfactory working of the kiln was found to admit of such changes as would give a variation in the sum of results between 97 and 107. Different types of charge naturally affect the total number of charges per 24 hours. As shown in Table III, the variation of resultant from 97 to 107 gives a variation in daily tonnage from 20 to 36 for the particular type of kiln under consideration.

Rotary Kilns for Fine Ore

In preparing ore for the kiln process of calcination there results a superabundance of fine material which cannot be used in the charge, for the whole content of the furnace must be porous enough to afford proper draft. This surplus of fine ore must be calcined in a rotary inclined kiln, the charge being fed at the upper or cool end and gradually working down toward the fire-box, in front of which the calcium product is discharged. Oil or coal is used as fuel for these rotary kilns. Calcination is less complete, however, than in the vertical type. The cost for labor is much less than in the method first described, and this suggests that some mechanical method of calcination must be devised if the process is to be utilized as a means of concentration in this country, where the labor cost is high.

The question of dust losses has been raised in connection with calcination as a possible objection to the process. There is, of course, some dust loss, and precautions must be taken to avoid loss of fine material in transportation. Nevertheless the process has been found highly profitable in certain places. Another objection is that the handling of the calcine is disagreeable to laborers, particularly when there is much lime in the ore. When lime forms a substantial constituent of the ore it is not advisable to expose the calcine to the weather for a long time, as that part of the limestone which has been altered in the kiln will slake and increase in weight and consequently reduce the percentage of zinc in the calcine. The zinc, however, suffers very little in this regard, and calcines transported by rail to the Atlantic seaboard and thence by boat to Europe, often several months en route, show little alteration.

Denver, Colo.

Photochemistry

A Lecture Delivered Before the Teknik Club in Denver

BY HARRY A. CURTIS, PH.D.

Everyone has observed that light may bring about, or at least hasten, certain chemical actions. That growing plants require sunlight, that wall-paper fades, that laundered linen is whiter when dried in direct sunlight, that our hands and faces tan in the summer, these are facts of photochemistry too evident to be overlooked. To a lesser degree the photochemical processes of photography are known to the layman, but the modern science of photochemistry is known only to a few investigators. It may, therefore, be of some interest to the readers of this journal to consider the broad outlines of a branch of chemistry which offers great promise of becoming vastly important to man.

It is not the purpose of the present paper to trace the development of the science of photochemistry, but rather to summarize the results which research in this field has yielded and to point out certain large problems which are now occupying most attention.

To discuss a highly specialized branch of any science in language which shall not be so technical as to bewilder the average reader of a scientific journal, and yet not lose that precision which a special nomenclature brings to any science, is no easy task. The attempt will be made in this article to steer a happy middle course between the inaccuracies which inhere in a popular discussion of a technical subject and the formidable language behind which every science finally takes refuge from popular attack.

The term photochemistry has unfortunately become associated with the better known word photography. It must therefore be pointed out here that photography is but one branch of a very much wider science, photochemistry. Photochemistry has been defined as the study of the effect of light on chemical reactions, the term light being used in its broader meaning to include the infra-red and ultraviolet regions of the spectrum.

Visible light includes waves of radiant energy whose lengths* lie roughly between 800 μ and 400 μ . This range is but a very short piece of the total spectrum of radiant energy, which is now known to extend from waves less than a millionth of a millimeter long up to those having a length of several hundred miles. It is instructive to give in Table I the various parts of this spectrum which have been investigated to date.

TABLE I—SPECTRUM OF RADIANT ENERGY

Wave-Length	Name of Wave	Investigator
0.01 μ to 1 μ	Röntgen or X-rays	Röntgen, 1895
1 μ to 100 μ	Uninvestigated	
100 μ	Shortest ultraviolet	Schumann, 1893
200 μ	Ultraviolet rays	Cornu, 1878
200 μ to 400 μ	Ultraviolet rays	Ritter, 1801
400 μ to 800 μ	Visible rays	Newton, 1666
800 μ to 1 μ	Ultrared rays	Herschel, 1800
1 μ to 10 μ	Heat rays	Lansley, 1886
10 μ to 61.4 μ	Heat rays	Rubens, 1896
100 μ	Heat rays	Rubens, 1910
218 μ and 343 μ	Heat rays	Rubens, 1911
343 μ to 1 mm	Uninvestigated	
4 mm	Shortest electrical waves	Lampa, 1895
6 mm	Electrical waves	Lebedew, 1895
		Hertz, 1889
1 cm. to 10 m.	Electrical waves	Lodge, 1890
		High, 1894
10 m. to 1 km	Electrical waves	Felderssen, 1892
1 km. to 100 km.	Electrical waves	Tesla
100 km. to 1000 km.	Electrical waves	Lodge, 1888

It will be seen in Table I that if the visible portion of the spectrum be called unity, then the total range represented in the table will be 2.5×10^4 . To get an idea of the magnitude of this ratio, suppose the length of

*1 μ = 0.001 millimeter;

1 $\mu\mu$ = 0.000001 millimeter.

the visible spectrum to be a meter. Then the total length represented would span the distance from earth to sun about 170 times. It is probable that radiant energy of every wave length will be found to have an effect on chemical reactions. As yet, however, research in this line has been almost completely limited to the visible and ultraviolet parts of the spectrum, to heat rays, and, in very recent years, to a few scattered investigations in the region of very short waves.

Available Sources of Light

Our greatest source of light is, of course, the sun. Professor Luther estimates that the sun delivers continuously to the earth about 200,000,000,000 hp., which is about 1,000,000 times more than is generated by all the engines on earth. Of this enormous quantity of energy, plants utilize a small portion, part is reflected away from the earth, and the balance is dissipated as heat. To store up and utilize a larger part of this energy with which the sun floods the earth is one of the dreams of photochemists.

While it is probable that any successful commercial process of photochemistry must utilize sunlight, it has been found that sunlight is a most unsatisfactory source of light for purposes of photochemical research. The difficulty is, of course, that the intensity of the sunlight is never constant for more than a few minutes at a time. Aside from this, the earth's atmosphere filters out the shorter waves of light, the very ones which are the most effective in most photochemical processes.

Of the various artificial sources of light, only a few are of sufficiently high intensity to be used in photochemical studies. The electric arc has sufficient intensity, but is difficult to keep burning steadily. The same difficulty is met with in the case of the electric spark, although several successful pieces of research have been accomplished using the spark as a light source. The Nernst glower burns steadily, and gives a continuous spectrum, but the light is not rich in the short waves. By far the most successful lamp for purposes of photochemical research are the mercury-vapor lamps. These are easy to operate, and give an intense light which is very rich in short waves. The spectrum of the light emitted is, of course, discontinuous. This is an advantage where it is desired to carry out research using monochromatic light, for if the light be spread out with a prism, any particular line may be used as a light source by simply screening off the rest of the spectrum. Where all the light is to be used, the spectrum may be enriched by replacing the mercury with an amalgam.

If the shorter waves of the mercury-vapor light are to be utilized, however, the lamp may not be constructed of ordinary glass, for this is not transparent to waves shorter than about 350 μ . Many attempts have been made to prepare glass which should be more transparent to the shorter waves. These attempts have been successful to the extent that glass has been produced at the Jena works having a transparency extending to nearly 250 μ . This, however, only partially solves the problem. There are indeed very few materials which do possess the desired properties. The lower limits of transparency of a number of common materials are given in Table II.

Of these materials, quartz is the one best adapted, and since the methods of working quartz have been developed, this material has found wide use in photochemical research, both in the manufacture of lamps and of all sorts of reaction vessels.

The Measuring of Light

The problem of measuring light in photochemical research is one which differs radically from the meas-

TABLE II—THE LOWER LIMITS OF TRANSPARENCY

FLINT GLASS.....	One centimeter thickness transmits from 50 to 80 per cent at 350 μ . Less than 1 per cent is transmitted at 305.
UVIOL GLASS.....	Lower limit at 253 μ .
FLINTOITE.....	One centimeter thickness transmits 83 per cent at 186 μ and the transparency is still high at 100 μ .
ROCK SALT.....	Transparency is high at 186 μ .
QUARTZ.....	Transmits 94.2 per cent at 222 μ and 67.2 per cent 186 μ ; at beyond 186 μ the transparency falls off rapidly.
CALCITE.....	Less transparent than quartz for short waves.
MICA.....	Strongly absorbs the short waves.
WATER.....	Transparency is high at 193 μ . At 186 μ it is less transparent than is quartz.
GLYCERINE.....	Transparency is high at 240 μ .
CANADA BALSAM.....	Transparency is high at 330 μ .
GELATINE.....	Transparent down to 253 μ .
AIR.....	Transparency is high at 194 μ ; at 186 μ the absorption is very high, and no waves shorter than 165 μ are transmitted.

uring of light for ordinary illuminating purposes. In the latter it is the visual result which is in question, and therefore any of the visual photometers may be applied. In photochemistry, however, the problem is usually to determine the rate at which radiant energy is being delivered to the reaction vessel. This at once eliminates all visual photometers, for the human eye is not equally sensitive to light waves of all lengths. It is most sensitive to yellow-green light, and is, of course, blind to the ultraviolet which is so active photochemically. Many chemical photometers, or actinometers as they are called, have been invented, but all of them have the same fault in that they are not equally sensitive to light of all wave-lengths. Ignorance of this fact has rendered of little value much of the early work in photochemistry.

One of the instruments most used for measuring light intensity in modern photochemical research is the thermopile. This instrument is based on the well-known fact that when radiant energy falls upon a junction between two different metals, that part of the energy which is absorbed heats the junction and will cause a current of electricity to flow from the one metal to the other through an external circuit. If a delicate galvanometer be included in the circuit, the current may be measured, and by comparing this current with that produced by a radiation of known intensity, the total radiation from any source may be measured. The radiation of known intensity is obtained from a so-called "black-body" radiator. Stefan discovered empirically, and Boltzmann derived by thermodynamic reasoning the law now known as the Stefan-Boltzmann law, which states that the total radiation from a perfectly black body is proportional to the fourth power of the absolute temperature. Stated algebraically $S = CT^4$, where S is the total radiation, T the absolute temperature, and C a natural constant having a value approximating 1.71×10^{-8} ergs per square centimeter per second. It is, of course, not possible to construct a "perfectly black body," in the sense here used, but the deviation of certain actual radiators from the ideal is negligible.

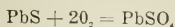
Another instrument often used to measure radiant energy is the radiomicrometer. In this instrument a thermopile and small circuit are suspended by a fine fiber between the poles of a magnet. When light falls upon the thermopile, a small electrical current flows through the circuit and the suspended system is turned by the magnetic field as in the D'Arsonval galvanometer, the effect being magnified by an optical lever.

Types of Photochemical Reactions

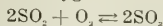
In general it may be said that light is capable of bringing about every type of chemical reaction. The number of photochemical reactions now known is far too large to allow a consideration of each one individually. We shall, therefore, only point out a few examples under each type of reaction.

Oxidation Reactions.

a. Lead sulphide is oxidized to lead sulphate by light and air:



b. Sulphur dioxide is partially oxidized to sulphur trioxide by light and oxygen:



Reduction Reactions.

Silver salts, iron salts, mercury salts, bismuth salts, etc., are reduced by light, the metal being liberated in some cases, in others a salt corresponding to a lower valence of the metal being formed. The ordinary process of blue-printing involves the photoreduction of an iron salt.

Polymerization.

a. Under the influence of light oxygen is converted partially into ozone, the equilibrium between the oxygen and the ozone depending upon the temperature and the intensity of the light used.



b. In organic chemistry a great many polymerizations have been accomplished by means of light. As a simple example we may cite the conversion of cyanogen into paracyanogen:



Depolymerization.

Ozone is partially decomposed into oxygen, the decomposition proceeding until the equilibrium point has been reached as in the formation of ozone from oxygen.

Allotropic Changes of the Elements.

Under the influence of light sulphur which is soluble in carbon disulphide, so-called S_λ , is converted into sulphur which is insoluble in carbon disulphide, so-called S_μ .

Likewise yellow phosphorus is converted into the red modification at a very much higher rate than occurs in the dark.

Isomeric Changes.

Light is especially active in bringing about isomeric changes in organic chemistry. For example, maleic acid becomes fumaric acid under the influence of light, ortho-nitrobenzaldehyde becomes ortho-nitrobenzoic acid, isocrotonic acid becomes crotonic acid, cumaric acid becomes coumarin, etc.

Light may also bring about stereo-isomeric changes, as, for example, in nearly all the fulgides, where the change is usually accompanied by a change in color.

Hydrolysis.

Hydrolyses, especially in organic chemistry, are readily accomplished by light. Thus acetone and water react to form acetic acid and methane:

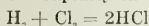


Ethyl bromide yields alcohol and hydrobromic acid:

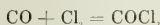


Synthesis.

a. Hydrogen and chlorine combine to form hydrogen chloride with explosive rapidity in direct sunlight:



b. Carbon monoxide and chlorine combine to form phosgene:



c. In organic chemistry a great many syntheses have been carried out by means of light, this method often affording a direct and simple means of carrying out reactions which may be accomplished only with much difficulty by other means.

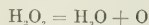
It has long been known that the halogenation of organic compounds is much hastened by exposing the reaction mixture to sunlight. In this connection it is interesting to note that a close parallelism exists between halogenation at high temperatures and halogenation in sunlight.

Decompositions.

a. Light decomposes hydrogen iodide very readily in the presence of oxygen or air:



b. Hydrogen peroxide is decomposed into water and oxygen:



The rate of decomposition is greatly influenced by the presence of a trace of foreign substance in the solution, in most cases the solution becoming more stable upon the addition of the foreign substance.

c. Under the influence of light of short wave-length, most organic compounds are decomposed into simpler substances. In Table III are given the decomposition products of a number of simple organic compounds.

TABLE III—DECOMPOSITION PRODUCTS OF ORGANIC COMPOUNDS

Compound	PERCENTAGE OF PRODUCTS					
	CO ₂	CO	H ₂	CH ₄	C ₂ H ₆	C ₂ H ₁₀
Methyl alcohol	5	8	87	..	..	..
Ethyl alcohol	..	22	63	..	15	..
Propyl alcohol	..	16	69	..	..	15
Formaldehyde	..	39	46	..	..	..
Acetaldehyde	5	39	33	6	23	..
Propyl aldehyde	6	37	37	..	..	20
Formic acid	59	21	19	1	..	..
Acetic acid	41	14	13	13	19	..
Propionic acid	41	15	15	15	19	14
Acetone	..	49	..	5	46	..
Acetone and water.	1	44	..	9	46	..

A Few Unsolved Problems of Photochemistry

I. THE CHLOROPHYLL PROBLEM

Chemical action may easily be caused to produce light; indeed artificial light was produced in no other way until modern times. To drive chemical actions by means of light is, however, a process about which but little is known, although it is a process which every growing plant successfully accomplishes.

The photochemistry of plant assimilation is now receiving much attention. In this process, carbon dioxide and water are the raw materials, carbohydrates the chief of the finished products. Between these two systems, carbon dioxide plus water on the one hand, and carbohydrates on the other, is a big gap in energy which the plant crosses by utilizing the energy of sunlight. The active agent in this transfer, the chief engineer if you please, is a certain green substance called chlorophyll, but beyond the fact that the goods are delivered on the proper side of the gap, not much is known about the process.

It is possible to manufacture carbohydrates from water and carbon dioxide in the laboratory. It is even possible to do this by means of light without the aid of chlorophyll. Here, however, an unfair advantage must be taken by using light of shorter waves than occur in sunlight. It seems probable that chlorophyll plays the part of a photocatalyst, by the aid of which plant assimilation may proceed in light of much lower waves than could otherwise be utilized. There are other examples of such photocatalysis or "optical sensitization," of which a familiar one is the use of certain dyes to extend the sensitiveness of the photographic plate into the yellow and red region of the spectrum.

In recent years much progress has been made by Professor Willstätter and his students toward solving the "chlorophyll problem" but much remains unknown about this photochemical process to which all the coal beds on earth owe their origin. Could we but learn to "speed up" the process of plant assimilation, as we can speed

up the process of combustion, sun-power would certainly become a factor in the industrial world.

II. THE LAWS OF PHOTOCHEMISTRY

A study of the kinetics of photochemical reactions is complicated by a number of troublesome factors, and progress in this line has been slow.

In order to be photochemically active, light must be absorbed. The fact of light absorption by a system, however, does not necessitate chemical action, since the light absorbed may be converted into heat. When photochemical action does occur, the degree of absorption is an important factor in determining the mechanics of the reaction. It appears that in reversible reactions with a large absorption of light, the velocity of the reaction becomes simply proportional to the amount of light absorbed per unit time, which is obviously a law analogous to the Faraday law of electrolysis. With an irreversible reaction having a small absorption, however, the mass law may be applied with a few modifications.

But little is known about the catalysis of photochemical reactions, which is not surprising in view of our almost complete ignorance as to the nature of catalysis in general.

The effect of temperature on photochemical reactions is much smaller than on other reactions. An increase of temperature of 10 deg. will usually double or treble the rate of an ordinary reaction, while the same increase of temperature seldom multiplies the rate of a photochemical reaction by more than one and a half, and in many cases has very little effect at all. It is well known, for example, that a photographic plate is nearly as sensitive at the temperature of liquid air as it is at ordinary temperatures.

The whole subject of photochemical kinetics is, as yet, much confused, and a great deal of quantitative experimental data are needed. There is undoubtedly some relationship between the chemical reactivity of a substance under influence of light and its molecular structure, just as there must be between its color, itself a photochemical phenomenon, and its molecular structure.

III. COLD LIGHT

The total energy radiated by a body is proportional to the fourth power of its absolute temperature (Stefan-Boltzmann law). This energy, however, is not evenly distributed in the spectrum, but for each temperature there is a characteristic distribution curve having a maximum at a certain wave length. As the temperature is raised, this maximum shifts toward the region of shorter waves. We are all aware of the qualitative operation of this law, that when the temperature of a body is gradually raised, heat waves are at first emitted, and later light waves of the longest wave length visible, i.e., red light. Obviously all "perfectly black bodies," i.e. such as follow the Stefan-Boltzmann law, would grow "red hot" at one definite temperature, while actual bodies, which differ somewhat from the ideal black body, will become red hot at temperatures which differ somewhat, but are not far from that of the ideal black body. All incandescent lamps operate on this principle, and the radiations produced are by no means limited to the visible regions of the spectrum, so that a considerable portion of the electrical or chemical energy used in the operation is wasted so far as the production of light is concerned.

So much for the ordinary emission of light. There are many cases known, however, where light is emitted from a body whose general temperature is far below red heat. Several kinds of luminescent bacteria are known; the fire-fly and glow-worm are common; phos-

phorus glows when exposed to air and moisture; fluorite emits a bluish-green light when gently warmed; certain sulphides will glow in the dark after a preliminary exposure to light; many chemical reactions are accompanied by the production of light at ordinary temperatures; crystallization is often accompanied by tiny flashes of light, and a similar phenomenon is to be observed when certain crystals are crushed.

In all these cases the light is produced at temperatures which are several hundreds of degrees below that which would be required by the ordinary laws of radiation. This phenomenon, the production of "cold light" by any of the above-named means, goes under the general name of luminescence. The mechanism of the process or processes is unknown.

That all forms of energy are mutually and quantitatively interconvertible is one of the axioms of physical science. The practical problem of converting one form into another is, however, a problem of gigantic proportions, one which has claimed the attention of men from earliest times. That the problem has in part been solved, is evidenced by the tremendous operations of modern industry. It is perhaps not too much to say that modern civilization could not have been attained had man not learned to transmute energy. There is, however, little room for pride in the achievement, for at every transfer much of the valuable free energy is spilled into the great dead-level ocean of heat to which every form of energy seems destined to revert ultimately. Engineers talk much of "efficiency" and seem to feel that the word lends a luster of achievement to their discourse. The real fact is that the word "efficiency" hides the chagrin with which they deliver at its destination so small a fraction of the total amount of energy which they bravely essayed to transform.

It so happens that some of the transformations are much easier to make than others; mechanical energy may be transformed into electrical energy, and vice versa, with but little loss, while in the transformation of heat energy into mechanical energy but little is saved. Among those transformations in which least skill is shown is the production of light. If produced through the chemical process of combustion, but a small part of the chemical energy liberated becomes light; the various electric incandescent lamps do better, but even here a considerable portion of the electrical energy is spent in producing waves of radiant energy far too long to be seen. To transmute chemical energy wholly into visible radiant energy is a problem which has so far utterly defied practical solution. The photochemist is still struggling with the problem. If therefore he is discovered hovering about some swampy place with a fine-mesh butterfly net, be sure that he is only pursuing common fire-bugs, although the results so far achieved in this line would indicate that he has captured only will-o'-the-wisps.

Coal and Coke in Canada.—The production of coal and coke in Canada during 1914 is the subject of an advance chapter of the annual report of the mineral production of Canada by the Department of Mines.

Removal of Logwood Embargo in Jamaica.—According to a telegram from the American Consulate at Kingston to the Department of Commerce, the embargo on logwood, logwood chips and logwood extract, including hematin crystals and other logwood preparations, has been raised.

The copper-nickel mattes produced by the Canadian Canadian Copper Co. and the Mond Nickel Co. in Canada are shipped respectively to New Jersey and to Wales for refining. Gold, silver, platinum and palladium are recovered as by-products from this matte.

Refrigeration in France*

BY L. MARCHIS

I—The Technique of Very Low Temperatures

The industrial production of liquid air, of oxygen, of nitrogen and of hydrogen, have, thanks to the labors of G. Claude, made great progress during the last few years. We shall here give in résumé the more important results of his researches.

1. PRODUCTION OF LIQUID AIR

Claude utilizes the external work produced by the passage of air from a high to a lower pressure, but he applies this well-known method in the following manner for the production of low temperatures.

The air compressed to a maximum pressure of 40 atmospheres, passes into a cooler where its temperature is reduced as we shall see at a later point.

This current of air, cooled and compressed to 40 atmospheres, is then to be passed into a cylinder where work is produced by expansive action on a piston. But before reaching this expansion cylinder, a part of the air is diverted from the main conduit. This diverted air, at a pressure of 40 atmospheres, reaches a cooled inclosure (liquefier) where the air is liquefied at the temperature of -140 deg. C. The remainder of the air (from which the portion has been diverted) then passes on to undergo an expansion by stages in a series of cylinders within which are pistons on which the air acts with the production of work.

The air, exhausted after the first expansion, is circulated about a first liquefier traversed by the diverted air (referred to above) at 40 atmospheres pressure. This air, which has undergone a first expansion, is warmed and then expanded in a second auxiliary cylinder. The air of the second expansion is sent into a second liquefier similar to the first.

Finally this air, twice expanded, is caused to circulate in the cooler where it operates as a cooling agent for the air compressed to 40 atmospheres which comes from the compressor.

For machines using a compressor of 75 hp., the delivery of liquid air is equal to 0.85 liter (0.224 gal.) per effective horsepower-hour.

2. SEPARATION OF THE OXYGEN AND NITROGEN OF THE AIR

Liquid air is especially important because it tends to become the only industrial source of oxygen and of nitrogen. The production, at a low price, of these two gases is a problem, the solution of which is of great importance for metallurgy and for the fertilizer industry. How may these two gases be derived from liquid air? This problem we shall now proceed to examine.

Oxygen and nitrogen are two substances of which the critical points are distinctly different, as follows:

— 119 deg. C. and 51 atmospheres for oxygen.

— 146 deg. C. and 34 atmospheres for nitrogen.

If, in the plane POT (OP vapor pressure ordinates; OT temperature abscissæ) we trace the curve of vapor tension for the saturated vapors of oxygen and of nitrogen, it will be found that the curve for nitrogen will lie above that for oxygen. At the same temperature, lying below the critical temperature, nitrogen is liquefied under a pressure higher than oxygen; at the same pressure, inferior to the critical pressure of the two gases, nitrogen is liquefied at a temperature lower than oxygen. Thus under atmospheric pressure oxygen is liquefied at -182.6 deg. C. and nitrogen at -194.4 deg. C.

3. SPECIAL CIRCUMSTANCES PRESENTED BY THE LIQUEFACTION OF AIR (MIXTURE OF OXYGEN AND NITROGEN)

The liquefaction of air, that is of the mixture of the two gases oxygen and nitrogen, presents certain special conditions which we must here note.

If, at a constant temperature T , sufficiently low, air is compressed in a closed chamber, the following phenomena are observed:

(1) At a certain value P_0 of the pressure, there appears the first drop of liquid; we shall designate the state of equilibrium characterized by the value P_0T by the term "dew-point."* For all pressures less than P_0 , the air is in the state of homogeneous vapor; from P_0 upward, separation of the air in two phases is produced.

(2) If, at the constant temperature T , the volume of the air is continuously decreased, the pressure rises; at the same time the amount of the liquid phase increases and the amount of the vapor phase decreases. If the increase in pressure is continued, the air passes entirely into the liquid state; the values P_0 and T of the pressure and of the temperature at this instant characterize what we shall term the "boiling-point."

For all pressures exceeding P_0 , the air is in the state of homogeneous liquid; for all pressures comprised between P_0 and P_0 , the air is divided into two phases, one liquid and one vapor.

(3) The "dew-points" and the "boiling-points," obtained at diverse temperatures trace in the plane POT (OP , ordinates; OT , abscissæ) on the one hand the line of dew and on the other the line of ebullition of the gaseous mixture considered.

The line of ebullition lies entirely above the line of dew; the two lines come together at the critical point, that is, in the present case, at the point for which the co-ordinates are 39 atmospheres and -140 deg. C.

(4) For each system of values (TP) of the temperature and of the pressure (T below the critical temperature and P lying between P_0 and P_c), there exists a state of equilibrium of the combination of the two phases in contact one with the other. In this state the compositions of the two phases are different.

(5) Let us apply the term "oxygen quality" of the phases, liquid and gaseous, to the percentage of oxygen (the more liquefiable element) in each of them.

The oxygen quality of the liquid phase is, in the state of equilibrium, always higher than that of the gaseous phase. The liquid is always richer in oxygen than the vapor.

When, at constant temperature the pressure rises, the oxygen qualities of the phases, liquid and gaseous, continuously decrease to the complete liquefaction of the mixture.

4. THE SEPARATION OF OXYGEN AND NITROGEN CAN NOT BE REALIZED WHEN, IN THE LIQUEFACTION OF AIR, THE LIQUID AND GASEOUS PHASES ARE MAINTAINED IN CONTACT

Thus when air is liquefied (volumetric content 21 per cent of oxygen) the first drop of liquid which is formed contains both oxygen and nitrogen and its "oxygen quality" is 47 per cent. The values of the "oxygen quality" continuously decrease in proportion as the volume of the liquid phase increases: It is thus that liquid at 34 per cent can only be in equilibrium with vapor at 12.5 per cent. But, so long as a gaseous phase exists, its oxygen quality is very different from 0; it remains greater than 7 per cent.

If the two phases, liquid and gaseous, obtained by the progressive liquefaction of air are maintained in con-

*A paper read before the International Engineering Congress in San Francisco.

*Note that this is entirely distinct from the dewpoint relating to water vapor and air. (T.V.)

tact, it is impossible to prepare gaseous nitrogen free of oxygen, that is with a sufficient degree of purity.

5. DISTILLATION OF LIQUID AIR UNDER CONSTANT PRESSURE

It is not the same, however, when, maintaining the pressure constant, the liquid phase is removed as rapidly as formed. In such case the phenomenon encountered is the inverse of that met with when liquid air is distilled under constant pressure. In this case the oxygen qualities of the phases, liquid and gaseous, continuously increase; these phases, separated one from the other as rapidly as formed, tend toward a content of pure oxygen; at the same time the temperature of ebullition rises from a value nearly that of pure nitrogen to the temperature of ebullition of pure oxygen.

6. CONDENSATION OF AIR UNDER CONSTANT PRESSURE WITH ELIMINATION OF THE LIQUID PHASE

Inversely, if, under constant pressure, air is progressively condensed, removing the liquid phase as rapidly as formed, liquids and gaseous residues are obtained less and less rich in oxygen; at the same time the temperature of condensation drops and tends toward the temperature of ebullition of pure nitrogen under the pressure considered. There is thus obtained a gaseous mixture richer in nitrogen than that obtained by leaving the liquid and gaseous phases in contact.

However, in order to obtain a gaseous residue sensibly free of oxygen, it is necessary in this method to liquefy practically all of the air.

7. THE COUNTER-FLOW METHOD OF G. CLAUDE

A better result is realized by the use of the method designed by Mr. Claude under the name of regenerative or "counter-flow" method.

Let us assume in any case the progressive condensation of the air and the removal of the liquid phase as rapidly as formed. But assume further that the liquid thus obtained meets, in separating from the gas, a gaseous mass richer in oxygen. The liquid is colder, as a consequence of the high percentage of nitrogen which it contains; a part of the more condensable oxygen of the gaseous mixture will then become liquid and will take the place of the nitrogen which is vaporized. Thus by a counter-flow circulation of the liquid and the gas of different oxygen qualities, there is obtained, on the one hand, a liquid very rich in oxygen, and on the other, *gaseous nitrogen practically pure*. The latter comes, furthermore, in large part from air treated but not liquefied.

Mr. Claude has realized as follows the principle of the "counter-flow":

A form of small tubular boiler is disposed in such manner that its axis is vertical. The tubes are surrounded on the outside by the liquid air. There is then passed into the inside at the bottom a current of cold compressed air. This in passing up through the tubes is progressively liquefied, producing both liquids and vapors less and less rich in oxygen. The vapors continue to rise toward the top of the tubes while the condensed liquid descends toward the bottom. This liquid, in falling into the lower receptacle, meets the gaseous portions rich in oxygen, and thus is produced the continuous exhaustion, of which the principle has been set forth above. There is thus liberated from the top of the nest of tubes practically pure nitrogen, while liquid specially rich in oxygen is continuously drawn from the bottom.

8. THE PREPARATION OF PURE OXYGEN AND OF NITROGEN 97 PER CENT OR 98 PER CENT PURE

A second stage remains to be realized. Instead of air with an oxygen content (volumetric) of 47 per cent., it is required to obtain oxygen practically pure. This is

realized by means of methods of *rectification* based on those employed in the manufacture of alcohol.

In a vertical column there circulate: (1) From bottom to top, oxygen vapor practically pure; (2) from top to bottom, liquid with a high percentage of nitrogen. The latter, colder, condenses the oxygen and allows its nitrogen to escape in the gaseous condition, according to the procedure above developed in the description of the counter-flow method.

The apparatus is composed of a sort of tubular boiler with axis vertical. This is extended on top by a sheet-metal cylinder of the type employed in the distillation of alcohol. The vertical tubes of the boiler are surrounded by liquid oxygen practically pure. On the inside and at the base of the tubes, air is led in under a pressure of 5 atmospheres. As has been explained above, this air is liquefied, giving a liquid air with excess of oxygen in the lower part of the tubes and nearly pure gaseous nitrogen in the upper part. The latter is carried through the liquid oxygen and is liquefied in turn. In consequence of its pressure, the liquid with excess of oxygen flows out continuously at the middle part of the rectifying column, while the liquid nitrogen, very poor in oxygen, overflows at the top of the column.

Furthermore, the oxygen which surrounds the boiler is vaporized, as a result of the disengagement of heat resulting from the condensation of the air in the interior of the tubes. This vapor of oxygen, in rising through the column, encounters liquids richer and richer in nitrogen. It is then condensed, taking the place of the nitrogen which is vaporized. Thus practically pure liquid oxygen falls back into the boiler, while pure nitrogen is liberated at the upper part of the rectifying column. The mass of liquid oxygen which falls back into the boiler is superior to that which is vaporized in rising through the column. The excess of oxygen is evacuated and carried through a cooler to the gasometer or point of utilization. This cooler serves to cool the air at 5 atmospheres pressure which is introduced into the base of the apparatus.

The ensemble of this equipment (cooler, liquefier, rectifying column) is surrounded by a thick layer of heat insulating material which opposes the inflow of heat.

The delivery of this apparatus is approximately 1 cu. m. (35.3 cu. ft.) of pure oxygen per effective horsepower-hour for the size producing 50 cu. m. (1765.7 cu. ft.) per hour; 1.2 cu. m. (42.4 cu. ft.) for the sizes producing 100 to 200 cu. m. (3530-7063 cu. ft.) per hour; 1.5 cu. ft. (53 cu. ft.) for the sizes producing 1000 cu. m. (35,300 cu. ft.) per hour, operating at pressures of 10 atmospheres at the most. For these latter, aside from the motive power, the costs (labor and fixed charges) will not exceed 0.01 franc per cubic meter of oxygen (0.005 cent per cubic foot). With the motive power available in the neighborhood of furnaces and waterfalls, the total cost of oxygen will result, according to Mr. Claude, about 0.02 franc per cubic meter (0.01 cent per cubic foot) or 15 francs per ton (density of liquid oxygen 1.33) (\$2.62 per ton of 2000 lb.)

At the present time the forty plants which are operating with the preceding apparatus (Liquid Air Company) are producing annually 24,000,000 cu. m. (847,000,000 cu. ft.) of liquid oxygen. Operating at the same time, they would furnish 3000 cu. m. (105,900 cu. ft.) of oxygen per hour while liquefying 40 tons of air per hour. The factory at Boulogne-sur-Seine operates with two units each of 150 cu. m. (5300 cu. ft.) capacity.

9. THE PREPARATION OF NITROGEN WITH 0.2 PER CENT OXYGEN

Nitrogen with 2 per cent or 3 per cent of oxygen, the preparation of which we have just described, cannot be employed in the manufacture of cyanamide.

In improving the method of rectification described above Mr. Claude has succeeded in preparing nitrogen containing not more than 0.2 per cent of oxygen (called nitrogen 99.8 per cent pure).

The principal fault of the apparatus for the production of pure oxygen consists in its insufficient production of liquid nitrogen. The residual gases coming from the progressive condensation of the air do not find, in passing again through the bath of oxygen, a medium sufficiently cold to completely condense them, but in the rectifying column there may be found a part sufficiently cold to secure the more complete liquefaction of the nitrogen resulting from the progressive liquefaction of the air.

It is for this reason that in the new equipment constructed by Mr. Claude the residual gases coming from the progressive liquefaction of the air, instead of passing into the liquid oxygen, are conducted through a serpentine liquefier placed in a sufficiently cold region of the rectifying column. Nitrogen, liquefied in this region, is led to the upper part of the rectifying column and flows from above downward, meeting the vapors of oxygen coming from the bath which surrounds the lower liquefier.

At the present time the Liquid Air Company, which is exploiting the processes of Mr. Claude, has in operation or under construction 18 units for pure nitrogen, each of 500 cu. m. (17,650 cu. ft.) capacity per hour. When they are all in operation at the same time, 3 tons of nitrogen per hour may be delivered.

10. THE PREPARATION OF HYDROGEN

Hydrogen is extracted from water gas. It is known that this gas contains on the average 50 per cent of hydrogen and 40 per cent of carbon monoxide. The separation of these gases is very readily made by the methods of Mr. Claude. However, the process has not as yet been carried to the point of industrial production. The Liquid Air Company is making experiments in this direction and is liquefying 150 to 200 kg. (330 to 440 lb.) of carbon monoxide per hour. This substance may be employed mixed with oxygen to form an explosive mixture available as fuel in an internal combustion engine.

11. THE EXTRACTION OF THE RARE GASES IN THE ATMOSPHERE

The counter-flow method of Mr. Claude has made possible the extraction from atmospheric air of the rare gases, helium, neon, argon, krypton and xenon. It secures, in fact, the possibility of gathering, as a by-product of the industrial manufacture of oxygen and of nitrogen, a mixture of nitrogen and at the least 50 per cent of rare gases, and more particularly of neon and helium.

To this end, the gaseous residues which are the most difficult of liquefaction are led, in the proportion of 6000 liters (1585 gal.) per hour for a delivery of air of 3500 cu. m. (123,500 cu. ft.), to the lower part of a tubular system cooled by liquid nitrogen. Under the simultaneous effect of the pressure of 4 atmospheres and of the very low temperature, the condensation of all liquefiable substances results.

The gaseous residue is constituted, if the delivery is properly regulated, of a mixture almost pure of neon and helium. An apparatus of a capacity of 50 cu. m. (1765 cu. ft.) oxygen per hour produces per day 100 liters (26.4 gal.) of neon or 30 cu. m. (1059.4 cu. ft.) per year.

Neon is now employed in tubes which light up with a rose color as a result of the passage of an electric current at high voltage. These lamps give approximately 200 cp. per running meter of tube and require about 0.6 watt-hour per candle power. By the intro-

duction of a little mercury into the neon tubes, a beautiful blue light is obtained.

12. LIQUID OXYGEN EMPLOYED AS AN EXPLOSIVE

Liquid oxygen may serve as an explosive. Cartridges composed of ordinary lampblack, dipped for a few moments in a bucket filled with liquid oxygen and primed with a fulminate cap, constitute a formidable explosive, as powerful as gum dynamite and costing only one-fourth to one-fifth as much as the latter.

13. PRODUCTION OF TEMPERATURES DOWN TO — 211 DEG. C. BY THE USE OF LIQUID NITROGEN

Hydrogen boils under atmospheric pressure at a temperature of — 252.6 deg., but this substance is still difficult to procure in considerable quantity. Mr. Claude has indicated a simple method for obtaining in a few minutes a temperature of — 211 deg. when liquid nitrogen is available. This process is more convenient, more rapid, and permits of operating with a restricted equipment, on quantities of liquid nitrogen greater than by means of evaporation under partial vacuum.

When there is passed into a liquefied gas a rapid current of air, the liquid is cooled very much below its normal point of ebullition.

The liquid nitrogen is placed in a Dewar-d'Arsonval tube freely open to the air. There is first passed in a rapid gaseous current of hydrogen, first cooled in liquid nitrogen. In the experiment, the rapidity of the current of hydrogen is gradually raised from 20 to 25 liters (5.3 to 6.3 gal.) per minute to 50 or 60 liters (13.2 to 15.85 gal.) per minute.

Under these conditions, a period of about twelve minutes is sufficient in order to lower the temperature of the liquid nitrogen to — 210 deg. C. From this point on, the temperature remains sensibly fixed. After twenty minutes, a temperature — 211 deg. is reached; a limiting temperature corresponding to the slow congelation of nitrogen. There may be thus realized a fixed point in a manner quite as convenient as those of the boiling points of oxygen and of nitrogen.

One might employ the same general method with liquid oxygen, but in this case the limiting lower temperature would be — 204 deg. In order to obtain with this substance the same temperature by a reduction of pressure, it would be necessary to boil it under 50 mm. (1.9685 in.) of mercury.

14. RECOVERY OF VOLATILE LIQUIDS. METHOD OF MR. CLAUDE

In several important industries (artificial silk of Chardonnet; smokeless powder; celluloid, etc.) costly liquids are frequently lost (alcohol and ether in particular) under the form of vapors diluted in enormous masses of air. Often, even in spite of a very considerable recovery, these losses in certain establishments may reach millions of francs per year.

Mr. Claude has proposed for this recovery a method which presents analogies with those which we have previously noted.

I—Air charged with water vapor and with vapors of alcohol and ether is compressed to a pressure such that it is sensibly saturated with water vapor at the temperature which it possesses at the end of compression, and in consequence, such that it will be saturated with water vapor after reaching its ordinary temperature. To realize this result, a pressure of 4 to 6 atmospheres is practically sufficient.

II—The compressed air is cooled in a refrigerator using water. As a result of its super-saturation with regard to the vapor of water, the latter condenses, carrying with it a little alcohol and other vapors, notably vapors of camphor (celluloid industry).

III—The compressed air, relieved of the larger part of its vapor of water, is then carried to the "recoverer." This is a sort of vertical tubular boiler. The compressed air rises from the bottom to the top through the interior of the bundle of tubes. A counter current of cooled air arrives on top of the "recoverer" and circulates from above downward around the bundle of tubes. The compressed air, in rising, meets with air colder and colder. On entering the bundle of tubes, the compressed air condenses out a mixture of water and alcohol. As this mixture can only be solidified at a temperature considerably below zero, there is no danger of an obstruction of the tubes by the solidification of the water. In proportion as the compressed air rises in the bundle of tubes, it deposits mixtures of water richer and richer in alcohol and in ether, that is to say, less and less readily congealed. These mixtures, flowing from above downward in the bundle of tubes, come into contact with regions continuously warmer. The danger of obstruction by ice is then less and less to be feared.

When the compressed air first arrives at the top of the "recoverer," or transformer, it may be subject to a temperature as low as -90 deg. C., a temperature at which the maximum tension of the vapor of ether is less than 0.5 mm. (0.0197 in.), but which is insufficient to congeal it. The collection of vapors accumulates in the liquid state in the lower receptacle, while the compressed air escapes from the top of the apparatus completely deprived of its vapors.

IV—This compressed air, exhausted of its vapors and cooled, is then carried to the cylinder of an engine where it expands with the production of work. This expansion produces a further marked reduction of temperature in the air. It is this air, at a temperature of -120 deg. to -130 deg., which, passed from above downward in the apparatus as a counter current in opposite direction to the compressed air, determines the program of descending temperature of which we have just analyzed the consequences.

V—It is preferable in the apparatus to push the refrigeration to the point where alcohol alone is separated. The ether is then in the way of separation disseminated in the air in the form of small globules. Carried along by the current of air from the bundle of tubes, it is then separated mechanically by its passage through a separator provided with pierced baffles.

VI—The following is a method of operation of the apparatus with regard to the production of low temperatures:

At the beginning all parts of the apparatus being at the same temperature, there is at first in the compressor a warming of air and a disengagement of heat which is absorbed by the circulating water. The compressed air enters the bundle of tubes in the apparatus at ordinary temperature, whence it flows out sensibly at the same temperature. The temperature of this air then becomes lowered in the expansion prime mover. This expanded air returns, chilled, into the shell of the apparatus; there it is warmed before escaping, but it cools the compressed air traversing the tubes. This air then enters the expansion prime mover at a reduced temperature, whence it issues, still colder and with capacity for still further cooling of the compressed air in the bundle of tubes, and so on from one round to another with reducing temperatures.

About one-half hour is required for the realization of the condensation.

With large units, where the initial compression need not exceed 4 kg. per square centimeter (56.89 lb. per square inch), as much as 16 cu. m. (565 cu. ft.) of air may be treated per horsepower-hour.

The Lyons Celluloid Company has made in its Oyonnax factory an installation for treating 200 cu. m. (7063 cu. ft.) of air coming from the laminators and dryers of celluloid. This air, aside from water vapor, is charged with vapors of camphor, alcohol and ether. The apparatus driven by a 25 -hp., three-phase motor, giving an initial compression of 5 atmospheres, secures the recovery each twenty-four hours of 150 kg. (330 lb.) of alcohol, 80 kg. (176 lb.) of ether, and 15 kg. (33 lb.) of camphor. In the expansion prime mover the temperatures are: At admission, -60 deg. C. and at exhaust -110 deg. C.

There is no danger of explosion. A warm explosive mixture with dry air and ether is not produced until the proportion of ether reaches 50 to 60 grams per cubic meter (0.0021 - 0.0037 lb. per cubic foot), but in these cases the mixture contains vapor of water and about 20 grams of ether per cubic meter (0.0012 lb. per cubic foot). Furthermore, the mixture is cooled in issuing from the compressor.

II.—Heat Insulators

Fourier's theory of the conduction of heat leads to the following propositions:

1. If a substance has two infinite plane parallel boundary faces, the quantity of heat which, under steady conditions, flows across a surface S from one of these boundary faces to the other is given by the equation:

$$Q = kS \frac{T_1 - T_2}{l} t \quad (1)$$

where Q = quantity of heat, S = area, l = distance between the two surfaces, T_1 , T_2 = temperatures of the two faces, t = time, k = coefficient of internal conduction of heat (thermal conductivity) for the substance.

2. Let us consider two media exterior to the substance under consideration and touching the boundary surfaces of this substance. In these media let us trace two planes parallel to the boundary surfaces of the substance and infinitely near to them. Let us call Θ_1 and Θ_2 the temperatures on these planes in the media which are in contact with the boundary surfaces of the substance under examination. If we consider an area S on these planes at temperatures Θ_1 and Θ_2 , we may, as soon as steady conditions are established, write the following relations:

$$Q = a_1 S (\Theta_1 - T_1) t = kS \frac{T_1 - T_2}{l} t = a_2 S (T_2 - \Theta_2) t \quad (2)$$

$$\left. \begin{aligned} \Theta_1 - T_1 &= \frac{Q}{St} \times \frac{1}{a_1} \\ T_1 - T_2 &= \frac{Q}{St} \times \frac{l}{k} \\ T_2 - \Theta_2 &= \frac{Q}{St} \times \frac{1}{a_2} \end{aligned} \right\} \quad (3)$$

Whence adding and solving for Q we find

$$Q = KS (\Theta_1 - \Theta_2) t \quad (4)$$

in which

$$\frac{1}{K} = \frac{1}{a_1} + \frac{l}{k} + \frac{1}{a_2} \quad (5)$$

K is the coefficient of transmission of heat from the one of the media at temperature Θ_1 to the other at temperature Θ_2 through the substance of thickness l . It is a coefficient of special importance in the refrigerating industry.

Mr. Biquard of the Conservatoire des Arts et Métiers, at Paris, has studied the various factors on which this coefficient depends.

He gives to the coefficient $\frac{1}{a_1} + \frac{1}{a_2}$ the name "insulating value" due to the boundary surfaces. If the conditions on the two surfaces are the same,

$$a_1 = a_2 \text{ and} \\ \frac{1}{a_1} + \frac{1}{a_2} = \frac{2}{a}$$

To the coefficient 1 K Mr. Biquard gives the name *overall insulating value*.

It is of interest to examine the influence of the boundary surface of the substance. This influence is only negligible when the values of 1 K are greater than 4. In this case the "insulating value" of the boundary surfaces is scarcely 5 per cent of the overall value. The latter is in such cases proportional to the thickness of the substance, the coefficient of proportionality k being the reciprocal of the thermal conductivity.

3. The experimental determination of this last coefficient is then of very great importance. Mr. Biquard has made his determinations in realizing, as far as possible, the conditions of Fourier's definition.

To this end he employs the method known in experimental physics under the name of the "guard-ring method."

Let us suppose that in a large plate of insulating substance (flat with parallel faces) we isolate, in thought, a cylinder of section S situated at a great distance from the rims of the plate. Let us assume that, without changing anything in the mode of propagation of heat in the ensemble, we measure the quantity which, under steady conditions, passes from one of these faces to the other of the cylinder of section S . Everything will happen as though the substance studied had infinite parallel faces. The propagation of heat in the cylinder of section S will not be modified by the presence of the sections surrounding it. In this manner, in the experiment, the conditions of the theory will have been realized. The part of the substance which surrounds the cylinder of section S is the guard ring. The breadth of the latter outside the cylinder of section S should be equal to about twice the diameter of this section.

Mr. Biquard has thus realized these conditions:

The insulating substance under examination is placed between two plates of copper maintained, one at 0 deg. C. by melting ice, the other at a temperature constant and definitely determined by means of a current of water. The ice is placed in two chambers separated by an insulating partition; one of these chambers corresponds to the cylinder of section S , the other to the guard ring. The plate of copper which is in contact with the ice, shows, furthermore, a groove limiting the cylinder of section S . The quantity of ice melted in a given time in the chamber which corresponds to the section S is then measured.

We give some of the results found by Mr. Biquard:

1. The smallest coefficient* of internal heat conduction seems to be that of Javanese kapock packed to weigh 15.7 kg. per cubic meter (0.97 lb. per cubic foot).

2. The coefficient of internal heat conduction of a heat insulator increases considerably when it has absorbed humidity. If one takes, for example, granulated cork mixed with tar, its coefficient of internal conduction equals 0.052 when the substance is dry (packed to weigh 275 kg. per cubic meter [17.1 lb. per cubic foot]). This coefficient becomes equal to 0.076 after a period of twenty days soaking in water, as a result of which the cork takes up 310 kg. of water per cubic meter (19.3 lb. per cubic foot) by way of absorption.

*In the advance copy of the paper from which this is reprinted, this value is given as "0.034 meter, calories-Kil-log, hour, per deg. Cent." It is not clear what unit is meant. If it means kilogram-calories flowing per hour through a section of 1 sq. meter for a thickness of 1 meter of the insulating material, this and the following figures do not seem to check with published figures at all. We trust that this will be cleared up in time. But as for the purpose of this paper the relative values only of the heat conductivities are of interest, the absolute values are of less importance.—Editor.

3. Insulators with intervals of air can only be employed when they can be maintained dry and the air quiet. In such case the most suitable thickness for the layers of air is comprised between 8 and 25 mm. (0.315 to 0.984 in.). If such layers of air are employed, it is indispensable to reduce to a minimum the thickness of solid matter, in directions both parallel and perpendicular to the walls.

From this viewpoint, the "fibrous cement" which, under a thickness of a few millimeters, present a satisfactory mechanical strength, seems likely to give good results.

The Grading Industries—II

BY EDWARD S. WIARD

(Continued from page 96)

Screens and Screening

The splitting of loose fragmental or granular material into three or more sizes and according to one or two linear dimensions of an opening, which is commonly called grading according to diameter, is almost universally done by screens; and these devices are by far the most important ones in the whole field of grading. If the components of a fragmental or granular mass are isometric, such as are cubes, spheres, octahedrons, etc., the characteristic of a perfect or theoretical grading resulting from treatment in a battery of screens is the presence of individual particles whose axial* measure is but little less than the width of apertures of the two screens which take part in the grading. If the aperture be square, the axial measures of the limiting grains will be a trifle less than the linear dimensions of the sides of the two squares. If the aperture be oblong, the limiting criterion will be the width of the oblong openings. If the holes in the screens be round, the largest and smallest grains in the perfect grading with isometric solids will have an axial measure but little less than 0.707 d where d is the diameter of the two sizes of aperture involved in producing the grading. Where the grains are round the limits will be but little less than d .

If the grains be of tetragonal shape, that is, prisms, ellipsoids, etc., with two axes of the same length but the third longer, the criterion of the limits of the grains appearing in a particular grading will be the short axes in the case of square and round holes, or all three of the axes if the apertures in the screen be slotted. Further descriptions of the limits of grading for regular figures might be stated, but these will suffice, for with very little extension of thought they will cover all regular figures.

If a grading be of fragmental material such as would result from crushed rock, then it is evident that if one axis is selected in a particle of such a grading, any other pair at right angles to one another and the first will, within certain limits, vary as to length, the length depending upon the point they intersect the first axis. Also as the first axis is rotated in various planes its length will change within certain limits as well as the two axes at right angles to it. What then is the criterion for the upper and lower limits of grading with material of this kind? It is impossible to state it in concise language; but quite evidently, fixing the mind on one axis as the direction axis in which a fragment is passing through an aperture of the screen controlling the upper limit of a grading, then all the other pairs at right angles to it and for any point of intersection with the first must define all planes which will be bounded by the aperture figure. Otherwise, as is evi-

*The axes are taken in the same position as minereological axes.

dent, the grain will be unable to pass through. The axes, of course, do not correspond with the extreme lengths of the planes which can be drawn through them. The extreme upper limit will be a fragment having only one direction axis through which the fragment can pass through the aperture. Evidently somewhere along such axis there is a plane at right angles to it which almost makes contact at three or more points with the sides of the aperture. By a similar course of reasoning the lower limit of a grading of fragmental material can be defined. These definitions are silent as to the shape of the grain. It must be plain on a little reflection that the limiting grains might be roughly cubical or longish prisms or be disks. It is possible to conceive a longish disk of no sensible thickness which would just pass through an aperture in a diagonal position. Later on it will be clear that while such grains may be conceived to report in the undersize of a certain screen they actually, in practical operation, report in coarser sizes.

Shape of Fragments

The eye is the best guide in most cases of commercial screening. Where the grains are more or less isometric the eye will detect variations from the limits of the grading very quickly unless the particles be very small. If the grading contains scaly and longish pieces the eye may be deceived, pronouncing the grading imperfect when it may be just the opposite. With many grading problems in crushed material which tends to fracture in a variety of shapes, good commercial results are often more desirable than theoretical perfection. In the grading of abrasives, for example, what is desired in a grading is cubical or rounded grains of the same general depth of cutting edge, or grains of the same average dimension or roughly of the same volume. On this account, consequently, longish and flatish grains will be more effective if they report with cubical and roundish grains whose diameter is greater than some dimension of the first kind of grains.

Crushed material like rock or ore yields fragments which are more nearly tetrahedral (see Fig. 8) than of other shapes. The tetrahedral shape is more particularly noticeable where the rock or ore is devoid of cleavage or fracture planes. With irregularly shaped fragments there will, of course, be re-entering angles and many minor sides, but the four planes of the tetrahedron will be found to more satisfactorily bound an irregularly shaped fragment than will a greater number. It is common to assume that rock fragments are more or less cubical but it is rare to find on them six major planes which correspond to the boundaries of a cube. Some writers have considered it convenient to consider all the grains of a grading as cubes having an edge equal to the average of the width of the two screen apertures which control the limits of the grading.

Products of Coarse and Fine Crushing

In the crushing of rocks and ores the useful energy absorbed is proportional to the area of surface made in the crushing. If the surface be calculated as resulting from cubical fragments there will be error, since the individual particles depart widely from this form. In making comparisons between the work of two machines in the point of power consumption, grading analyses followed by computations of the character

which have been mentioned will show which machine is consuming the greater proportion of useful energy. It would be expected however that the shape of the fragments would change as the pieces are successively reduced in size. In coarse-crushing operations, cleavage or other pre-existing planes will largely determine the faces in the fragments of broken rock or ore. As the rock or ore becomes more and more finely reduced, pre-existing planes will more and more disappear and the particles will more and more approach ones with perfect isotropism. On this account if comparative tests are to be made with two machines they should be done with the same kind of material.

There is also some variation in the mode in which various crushing machines do their work. Where the machine applies pressure directly to the rock fragments they give way by shearing along planes inclined to the direction of application of pressure. The coarse-crushing machines break in this way, but fine-crushing machines break also by grinding actions to some extent, and the production of surface by grinding takes less power than by shearing. Grinding actions tend to round the grains, and since in the perfectly rounded grain the surface is to the surface of the cubical grain in the ratio of 3.1416 to 6, the cubical rule will report too much useful power absorption. In the fine-crushing machines there are large masses to be moved, either to do the crushing or else power must be employed to move the ore or rock from the point where it enters the machine to the point where it leaves. In some tests made by Phillip Argall at the Independence mill the friction load required for driving a Chilean mill empty was 9 hp.; with a light feed the power increased to 28 hp.; with heavy feeding, to 63; and at the limit of loading the power required was 70. Of course, the bulk of the power used is employed in raising the mullers, and the height to which they are raised increases with the load; but at the same time, as must be evident, considerable increases in power result from moving the greater masses of ore in the mill as the load increases. In coarse or medium-crushing machines the power not usefully employed is almost entirely due to the friction caused by the thrusts of crushing. This is almost exactly the case with rolls running under favorable conditions; for they are perfectly balanced machines.

A much greater source of error in assuming that the average diameter of a grading is the average of the width of the two apertures will be discussed a little later. For theoretical discussions there is no reason why the irregularly shaped particles cannot be assumed by isometric figures of equal volume, and in some discussion which follows the grains are conceived to be spheres, this shape offering the least obstacle to concise statement.

Effect of Overloading Screens

In grading with screening machines and hand screens with material less than $\frac{1}{4}$ in. in diameter, the lower limit of a grading will appear of very much smaller size than fixed by the smaller of the two apertures. In commercial grading where capacity is desired rather than precision of work, the lower limit of a grading is very much below the size fixed by the aperture. This will be evident by reference to Fig. 9, which shows an extreme case of overloading with a revolving screen and with consequent poor definition of the lower limit of the screening. The sample analyzed by a screening test, and with results as plotted on the figure, is supposed to represent material which has passed through a screen with round holes 18 mm. in diameter and has failed to pass a screen with round apertures 12 mm. in diameter. Only the cross-hatched area pictures grains which

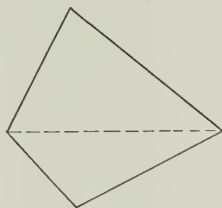


FIG. 8 — TETRAHEDRAL SHAPE

properly belong to the grading, the excess of finer material being due to the inferior work of the screening machine and overloading. In testing the sample with hand screens the individual pieces which remained on the 12-mm. and 8-mm. test screen could readily be picked up by the fingers and tried in different axial positions to see if they were not really particles of undersize. The test work with these two hand screens is consequently 100 per cent or perfect. The sample represents extremely poor work, there being 70 per cent of the material which does not belong in the grading.

In the majority of the rock-crushing plants of the East and the ore-crushing plants of the West, the screening work will average to an efficiency of 60 per cent, there being 40 per cent in different gradings which do not belong with them. In the most precise commercial grading, the best work being done in the abrasive industry, the efficiency of the work does not actually run much over 75 per cent. As shown by hand screens the work is better than this, in some cases over 90 per cent. In making the statement about the efficiency not

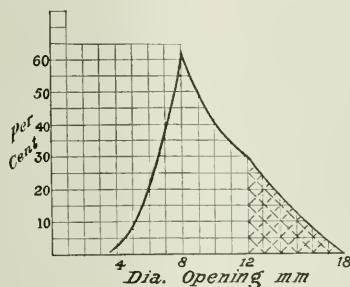


FIG. 9—SIZING TEST ON MATERIAL PASSING SCREEN WITH 18 MM. ROUND HOLES

exceeding 75 per cent I have in mind a very precise mode of measurement, the unaided eye not being deemed a sufficiently accurate guide and hand screens with the finer sizes but little better.

Efficiency of Screening

If the work of a battery of screens be x per cent or any percentage less than 100 or perfect, and some particular grading, such as a $+20-12$ -mm. size, be closely probed with screens with apertures differing from one another by 1 mm., there being test screens with 19, 18, 17, 16, 15, 14, 13, 12, 11, 10 mm., etc., holes, what would be the result? There has been no experimental work to tell; but in advance of the theory it can be predicted that the plot for the number of grains resting on each size would be a hyperbola until that screen size was reached. The number of grains would then begin to decline and the curve would take a downward direction from the node and would be a hyperbola with convexity facing that of the first leg of the curve. See Fig. 10, in which diameter of grain is plotted along the axis of X , ranging from 0 diameter at the origin to 20 mm. Axis of Y is plotted for the number of grains resting on the different test screens and of uniform number for sizes above 20 mm. A little reflection will make plain that if the plot is of the form mentioned, any grading of less than 100 per cent perfection will show the greater number of grains in a grading averaging nearer the lower limit of size as defined by the smaller of the two apertures entering into a grading than the upper.

The manner in which the fragmental material has

been prepared for the grading will to some extent modify the relations shown by the curves, and they are only strictly true when there would be present in the mass fed to the 20-mm. screen the same number of fragments or grains of every size. It is, of course, impossible for the mind to conceive of more than one individual in a grading of fragmentary material of any exact volume. Again the orderly mind will be certain that there will be many sizes lacking. But let it be conceived that all the individuals of a grading can be grouped into three-dimensional isometric objects of different size, but varying from one another by regular but sensible differences in dimension and that there are equal numbers of such objects; then the plot shown in the figure will follow. The plots are based on percentages of perfect work by weight, from 60 per cent upward. As the screening work approaches 100 per cent the fewer the grains of undersize there will be in a grading and the more nearly will an arithmetical average of the width of the apertures express the average width of the grain in the grading.

Distribution of Sizes in Crushed Material

If a crushing machine be fed with fragments all of which are larger in some dimension than the discharge opening, the screen analysis of the crushed mass will show a heaping up of fragments of sizes near that of the discharge opening, and a very rapid falling off in percentage of material below such sizes. If the material fed to the crusher contains all sizes, but the bulk of it coarser than the discharge opening, then sizes below or near the discharge opening of the machine will not show such a marked falling off in percentage, although there will still be a marked heaping up of percentage in sizes near the discharge opening of the machine.

If after leaving the crushing machine the entire mass is further subjected to comminuting actions reducing it to successively finer sizes, then the heaping up which is found in the coarse-crushing gradually passes to the other end of the plot so that in very fine crushing the bulk of the weight is represented by very fine fragments. See Fig. 11.

The point to be observed for the present is that for any particular grading resulting from the screening of crushed material there may be lacking grains of a certain range of size, and in exploring any particular grading with test screens varying from one another by only slight differences of width of aperture, there might be a heaping up on some of the test screens and reverse conditions on others. It must be plain in any case that

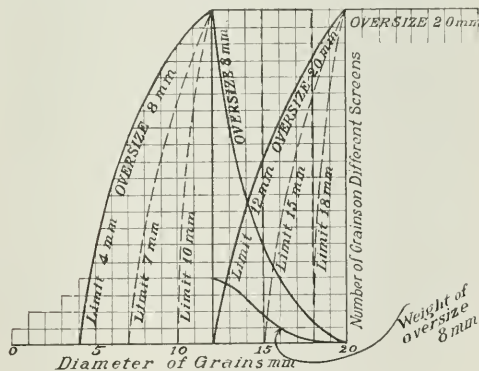


FIG. 10—PLOT OF GRAINS

the arithmetical average of the width of the two apertures does not represent the average size of a grading.

Probability and Chance in Screening

For power-driven screens the question of the degree of freedom with which grains of various size pass through the apertures is one that can best be understood from the mathematics of probability and chance. In the ensuing theory it is assumed that the fragments or grains approach the openings in a layer 1 grain deep and that there is no interference by other grains with a grain approaching an aperture. To put the problem in the simplest form let it be assumed, Fig. 12, that there is a square-meshed opening of length of side l , the thickness of wire or stock between holes being nil. Approaching the border of the square from any direction, and with a rate of speed some elements of which will be indicated later, is a spherical grain of diameter l/n , n being assumed to be of any value equal to or greater than 1. Then evidently for the grain to fall entirely within the square it must pursue some path marked by its center projected, such that at some point in its path the center projected will fall inside the concentric square of side $l - l/n$. A little reflection will show that the chances of the grain falling through the square are in the ratio of the area of the inner square to the area between the inner square and the outer, or

$$P = \frac{l^2 - \frac{l^2}{n^2}}{l^2} = \frac{n^2 - 1}{n^2}$$

which reduces to $\frac{n^2}{2n-1} - 1$. The inverse ratio fixes the chance of the grain *not* passing through, and is also a measure of the number of squares a grain will have to pass over before falling through.

It will readily be noted that this statement of theory places the problem in its simplest form. It would be expected that if the grain were placed in any position

such that its center of gravity were within the square it would fall through the square. All such questions which by extension include impact on the sides of the aperture, the effect of which will depend on many factors, such as the angle of impact, size of particle, velocity of its motion, etc., are not considered, and, as already stated, the question of the interference of the grains with one another is not considered. The question of their interference with one another when screening *en masse* will be touched upon. The mere change of direction by impact does not modify the theory but helps it.

If the square be made with side 1 in., and n be made 8, 4, 2 and 1, the following tabulation can be made of the chance of falling through the square of 1-in. side, and the probable number of squares which grains of $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$ and 1 in. will have to cross before falling through the 1-in. square.

Size of Grain	Chance of Falling in Square, Side 1 In.	Probable Squares	
		1 in. Side to Cross, Proportional to	
$\frac{1}{8}$ in.	3.27	0.31	
$\frac{1}{4}$ in.	1.29	0.78	
$\frac{1}{2}$ in.	0.83	3.00	
1 in.	0.00	Infinity	

The number of squares to cross is taken under the simplest possible assumption, viz., that the probability of a grain falling through begins *de novo* at each opening and the grains do not follow any regular path.

If values of l , l/n be plotted as y and x as the chance, then the hyperbolas which are obtained are symmetrical, the radius of curvature increasing as the value of l increases. The average value of P , or the chance, will represent for any screen having opening side l the average chance of grains passing through from sizes l to 0. Evidently P is the area bounded by the curve between the limits y -equals-infinity and x -equals- l , and the axes of Y and X , and this area divided by l . There can be no quadrature of this area, but an approximate expression can be obtained by considering the curves as equilateral hyperbolas, taking the measure for l in a unit sufficiently small so as to substantially produce a curve of this type, and then considering the curves as tangent to the axes at distances l and to equal the quarter arc of a circle of this diameter. When the average chance is determined from figures of this kind very evidently it increases as l increases. It is in direct proportion to l . A more exact mode of solution would be to take l/n sufficiently small for the first term plotted, so that while the position of x would be at a comparatively great distance from the origin it would be a finite distance. If this be done the value of P can be determined by the methods of the integral calculus, giving as before a value for P which increases as l increases.

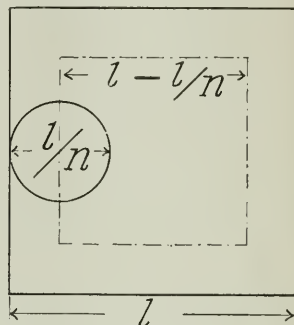
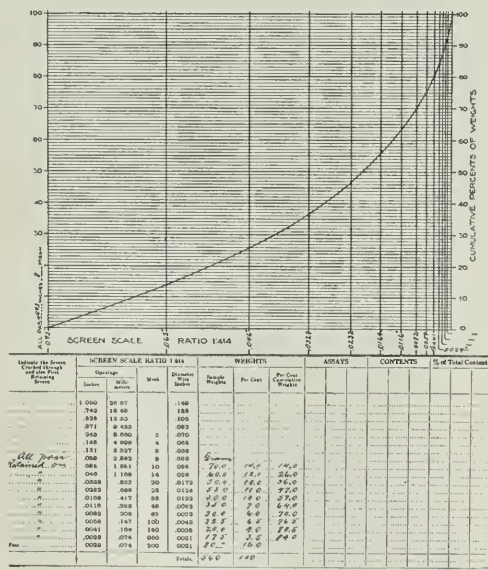


FIG. 12—SQUARE MESHED OPENING



greater extent, and this amounts to the same thing as the first statement. Further screening devices of the same pattern and size will have decreasing efficiency or capacity when provided with successively finer screens.

Influence of Other Factors

The question of the velocity of approach towards the screen opening will be considered for the case where the grain approaches the square at right angles to a side and along a line passing through the center of the side. The equation of a fall parabola with origin at the edge

of the opening is $x^2 = \frac{2V^2y}{g}$, where V is velocity of

approach of grain in feet per second and g the acceleration of gravity. The maximum permissible velocity with the position of path assumed is obtained when $x = l - l/n$ and $y = l/n$. Substituting these values, V becomes equal to

$$(l - l/2n) \sqrt{\frac{ng}{2l}}$$

When n equals 1 the conditions are obtained when the chance of the grain going through the aperture becomes 0, and V becomes equal to

$$(l - l/2) \sqrt{\frac{g}{2l}}$$

The shortest straight line path will be one which will bring the grain tangent to two sides of the square at some point in the travel, and the longest when the grain pursues a diagonal of the square.

It has already been pointed out to what degree test work with hand screens will permit of tests 100 per cent efficient, or perfect. With fine screens the degree

of elimination of undersize will depend upon the time spent shaking the individual test screen; but even after prolonged action of this kind there will remain many grains of very nearly the size of the openings. With machine screening the problem is different, for the fragments have only a limited amount of time for treatment, and during this time they must either pass into the undersize or discharge from the screen as oversize. Other things being equal, the screening device which yields the fewest number of undersize grains in the oversizes will be the best. In the curve Fig. 10 I have followed the theory under the assumption that the two screens, the 20 and 12 mm. sizes, will show an efficiency of 60 per cent. Under the theory the 12-mm. screen should show a different efficiency, but the tonnage reaching it is less and these two factors offset one another. No attempt has been made to measure the effects of these two opposing factors.

In Fig. 13 a curve is shown of the number of spheres below 20-mm. size required to make one sphere of 20-mm. size. From these data the weight curves on Fig. 10 have been computed and plotted.

Interpreting the Chance Law

Some further explanation may clear up some difficulties which may arise in the reader's mind. It has been stated that one ratio of the areas which have been mentioned represents the chance of the grain going through an aperture, while the inverse ratio represents the chance of its failing to go through an aperture. It has been stated further that this ratio is also a measure of the number of apertures which the grain has to cross before being eliminated if it is an undersize grain. Now on the plot for the 20-mm. screen the lower limit of undersize grains which will pass into the oversize has been fixed at 12 mm. If there be barely enough apertures passed over to eliminate all the 12-mm. grains, then all grains larger than this should report in the oversize of the 20-mm. screen, for the larger grains have not had enough apertures to pass over. I believe the reader will overcome this difficulty if he considers that while the inverse ratio is a measure of the number of squares to cross, it is the probable number of squares to cross for one grain.

The proper conception of the plot will be obtained from the following considerations. Let it be assumed that any particular size represents the lower limit for the oversize, and that there are A grains of each size, including the lower limiting size and the ones larger. Let x be the area of the chance inner square for any particular sized grain, and y the area between the inner and bounding square of the aperture. Then of A grains approaching a line of apertures of the lower limit of size, the fraction $x/x + y$ will pass through the screen and the fraction $y/x + y$ will remain in the oversize. These will be the fractions removed and remaining respectively after passing the first line of holes. Of the grains remaining there will be eliminated at the second line of holes a similar fractional part $x/x + y$, and so on, until after a sufficient number of lines of holes have been passed, all the lower limit of size has been removed. For the same number of lines of holes the proportion of undersize grains of larger sizes can then be determined, and on this being done a curve will be obtained similar to those of the oversize portions of Fig. 10. The undersize curves can be obtained by difference. I believe this explanation will also cover the difficulty in interpreting the chance law from the curves. As the law has been stated at an earlier point, there should always be fragments of all sizes in the oversizes and the plot of an oversize should pass through the origin; but the chance law is only for one aperture, and

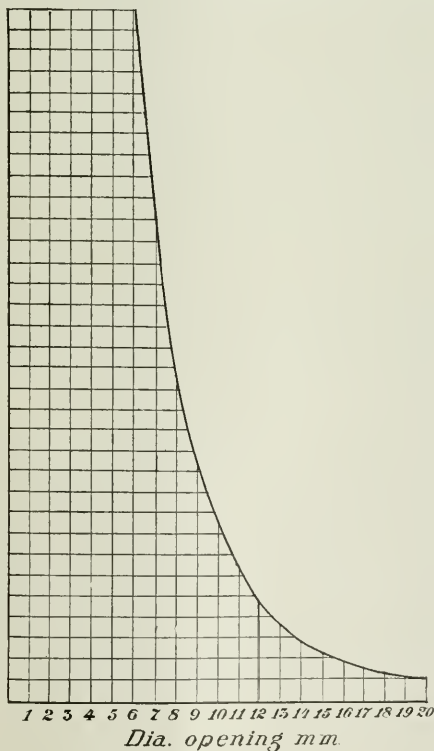


FIG. 13—SPHERE DIAGRAM

in actual screening the grains pass over many apertures, each removing its burden of grains which do not belong in the oversize; consequently the chance law for actual screening operations must be taken in the manner explained above.

The limit of the undersize grain which does not belong with an oversize grading may be raised to any desired amount. For the 20-mm. screen, the lower limit instead of being placed at 12 mm. can be placed at a higher point between this one and 20 mm. Curves where the limit is at 15 and 18 mm. are shown. For the 12-mm. screen the limit instead of being at 4 mm. can be placed anywhere between 4 and 12 mm. Curves are indicated for 7 and 10 mm. limits. The position of the curves depends upon the number of apertures passed over. Theoretically only when an infinite number of squares have been passed over can the work of the screens be perfect, when the curves of oversizes would be straight lines. If all the grains are not treated alike, that is, do not have the same opportunities for passing over apertures, then the plot will not follow. This discordance will arise when a screen is heavily overloaded. In this case exceedingly fine grains often do not have a chance to come into contact with the screening surface at all and pass into the oversize without having undergone any screening action. Note the minus 200-mesh grains of Fig. 11, illustrated on a Tyler cumulative diagram of a screen analysis.

Unit Capacity for Flat Screens

In order to determine the capacity of flat screens for varying sized feeds, uniform conditions must be imagined. If the adjustments of a screen to which material averaging $\frac{1}{2}$ in. diameter is fed are (1) length of stroke 1 in., or somewhere proportional to the diameter of the largest material fed, and (2) number of strokes 200 per minute; then if $1/50$ -in. material be fed it is quite evident that to give the grains equal possibilities as to chance the stroke must be reduced to $1/50$ in. If this be done, the only way the capacity of the screen can be made equal to the first case would be to increase the number of strokes 50^2 times 200—an impossible number and contrary to the opening statement of this section. If the length of stroke be reduced to $1/50$ in. while the number is maintained at 200, then evidently the capacity is only $(1/50)^2$, or, in other words, the capacity is proportional to the diameter squared. If the length of stroke be maintained at 1 in. and the number of strokes be as before, 200, then evidently the capacity of the screen is proportional to the diameter. The efficiency of the screen will, however, be markedly inferior to that where it is being fed coarse material. If the diminishing average chance be considered, which falls off from size to size directly as the diameter is reduced, then evidently when all factors are equal the capacity of a screening machine varies as the cube of the diameter of particle fed. Commercial figures of capacity lie between those proportional to d and d^3 . With regard to the fine sizes it is to be observed that the eye will not detect much error in the oversizes, and a hand screen is not much superior in this respect. In the abrasive industries all that the trade demands is that the grains of a grading appear of about the same size.

Ordinary shaking screens have an advancing speed not to exceed 50 ft. per minute. The number of strokes does not exceed 300; consequently to attain an advancing speed of 50 ft. per minute the stroke has to be 2 in. or better. In actual practice it is nearer to 25 ft. per minute.

Capacity of Belt Screens

The Callow belt screen has belt speeds ranging from 34 to 100 ft. per minute. The capacity for a duplex

screen made of two endless screen-cloth belts, each having a width of 2 ft., is given by the makers as follows:

Mesh	Opening, In.	Capacity, Tons 24 Hrs.
20	.027	250
30	.0145	200
40	.011	150
60	.00916	125
80	.00675	100
100	.0055	75
150	.0041	50

These figures apparently have been determined by taking the capacity of the screen belt at the maximum speed, the grains being considered to be one deep. It follows roughly the rule for diameter. In determining the capacity of flat shaking screens, I believe 10 tons per day of twenty-four hours per square foot of screen surface, for a product ranging in size from 1 in. to 0, represents the average load. For the most precise work this figure can be regarded as the base figure also, and the square root rule followed. Under the direct ratio rule a 12-mesh screen with 0.054-in. opening would have a capacity per square foot of $0.027/0.5$ times 10, or 0.54 ton per square foot of surface per twenty-four hours. Under the square rule the capacity would be $(0.027)/(0.5)^2$ times 10, equals 0.029 tons per square foot of surface per twenty-four hours. For a 4-ft. by 5-ft. screen the capacity with inch material would be 200 tons per twenty-four hours; for 12-mesh material, by the direct rule, the capacity would be 10.4 tons, and by the square rule, 0.6 tons per twenty-four hours. These rules are only intended to apply to problems where there are successive screening operations from coarse to fine. If the problem be the use of a single screen of fine mesh to remove fine particles from a mass containing all sizes from coarse to fine, the average diameter of the particles fed will govern the capacity.

Some factors affecting capacity I do not deem worth while touching upon. Friction would be greater with the fine screens, if the apertures of a screen be considered pipes for the transport of material, for even if the stock of which the screen is composed is reduced in thickness to a degree proportional to the width of the aperture, since the number of apertures per unit of surface increases as the reciprocal of the square of the opening, the opposition to discharge must increase as the linear number of meshes increases. As a matter of fact the ratio of the weight of stock in the screen per unit of area to the area of opening increases as the number of apertures per linear unit increases, and consequently the increase of friction as the size of the apertures is diminished is something more than can be expressed by a simple ratio.

With most fragmental material produced by crushing there is an excess of the finer sizes, so with screening machinery uniform as to stroke, shape, etc., what may be proper in the way of a screen at the head of a single line of screens will show overloading for finer sizes under the rules given. But such discrepancies will have to be disregarded in practical designing, the capacity being fixed for the screen with largest apertures and the rest doing the best they can. In this connection it will be stated again that while with coarse sizes the eye will detect variations in the diameter of a very small percentage among the different pieces of an oversize, with the fine sizes it will be ignorant of variations amounting to 100 per cent or even greater. In testing with hand screens the individual screens are shaken until the eye is satisfied; and the eye being the final criterion of commercial screening, much greater capacity is satisfactorily obtained than would be permissible if exact criteria of the efficiency were used.

If a screen of any particular size receives a feed which covers it one grain deep, then if the width be diminished by a half the screen must be covered with a layer

two grains deep. If now the screen be made twice the original length then evidently the second arrangement of surface is as efficient as the first, other things being equal, unless the proportion of oversize in the feed to the screen is very great. Where the proportion of oversize of a feed is large, a broad short screen is called for. For usual screening problems a ratio of length to width of 2 : 1 is preferable. The principal objection to wide flat screens is the difficulty of distributing the feed over them. If proper distributing means are adopted there is much loss of head room. One of the principal advantages of horizontal or nearly horizontal revolving screens is that they require no distributing devices, the material to be fed being merely dumped or fed in at any convenient point. Capacities of revolving and other types of screens will be discussed later.

Denver, Col.

Lutes and Cements

A paper read at the Baltimore meeting of the American Institute of Chemical Engineers.

BY S. S. SADTLER

I use the words *lutes* and *cements* together for two reasons. First, because they have different meanings, the former referring to temporary applications and the latter to more permanent uses. Second, the use of these words conjointly shows to a casual reader that the subject of this paper is not solely with reference to Portland cement.

Quite a few years ago I read several papers on the present subject. In these papers I classified the formulæ according to composition in one instance and according to intended use in another. These papers were noticed by a number of people who communicated with me, particularly engineers.

It is very difficult to give proper credit for what one finds in the literature, as some of these formulæ are like humorous stories that are rarely traceable to a source. In looking up this subject for the present occasion I noticed some eight or ten attractive formulæ in a well-known handbook of industrial chemistry. These were credited to a periodical which I soon found quoted one of my papers, and I was not the originator of more than a few of them. Thus, things are passed on. The value of the formulæ was diminished, however, by reason of the space allotted and the changes made.

I will classify the formulæ now as I did before the Engineers' Club of Philadelphia, by the use of the following subdivisions. Very few of the formulæ given herewith have not been tried by me. The only instances are where the authority was excellent and adequate trial was not practicable for some reason.

1. Waterproof

Of the chief bituminous substances available we have pitches, asphalts, gilsonite and blown petroleum residues, mixtures of these substances and mixtures of the same with inert material.

(a) Of the asphalts I prefer a substance like refined Bermudez, as it is nearly pure bitumen and forms homogeneous solutions with suitable solvents. A minor percentage of boiled linseed oil or blown petroleum oil is useful sometimes for tempering or fluxing. For solvents heavy naphtha is generally used. It does not dissolve all the asphalt, such as the so-called asphaltene portion, but it thins out the asphalt well enough. Coal-tar naphtha is better but more costly. As voids are very apt to form in a painted asphalt coating, some form of filler is generally employed, either by coating paper so that it becomes more or less impregnated or by the addition of a filler, such as silex, infusorial

earth, etc. The natural mineral filler of Trinidad asphalt may serve the purpose of such filler.

(b) For a soft, water-tight coating in cement work, blown asphalt and infusorial earth, thinned with a solvent, such as heavy naphtha, is employed.

(c) The use of blown asphalts with natural asphalts and gilsonite is in some cases desirable, as these products are ideal fluxes for hard asphalts and tend to prevent brittleness or separation of the films when the solvent evaporates. The harder or higher melting point grades of these blown residuums are capable of making good cements alone or with filler, but are rather hard to dissolve. Such artificial asphalts have melting points as high as 150 deg. C., while the softer ones that are probably best for fluxing have melting points about 80 deg. C.

(d) Lutes of boiled linseed oil, thickened with clay, asbestos, red or white lead, etc., are waterproof, if thick enough from the filler added.

(e) Flaxseed meal made into a stiff paste with water is useful as a lute for steam connections and is easily applied.

Portland cement only serves as a waterproof cement when given time for the preliminary setting to take place. It is not generally impervious to water, and because of its colloidal character while setting it seems hard to realize that it could ever act other than as a water pervious diaphragm. But when fully or reasonably well set and dry the colloid character no longer exists and does not return to these particles that have taken part in the setting from hydration.

For all practical purposes the use of trade preparations, such as those containing metallic soaps or oil emulsions, serves to render concrete approximately impervious, but I will refer to a few points I have noticed in making or using lutes and cements.

(f) For making small experimental electrolytic cells, etc., for demonstration purposes, I have found it desirable to use white iron-free Portland cement and white plasterers' sand that had been sieved. If a one-to-two mixture is made with the prescribed quantity of an approved waterproofing substance, such as the product of the Newberry patent, and care is taken to work out voids and the article in the green is kept moist, a very nice waterproof container can be made. It will also stand dilute acids or alkalis, but not the two alternately. For large articles wire-mesh reinforcement is often desirable, and if the vessel is used for dilute acids this might well be made of a mesh of Monel metal, etc.

(g) In the literature on this subject, if it can be dignified by that appellation, one finds frequent reference to making lutes with Portland cement and silicate of soda. Some of these may work and others will not, and I approach them with caution. A little silicate of soda in the water will help toward a quick initial set, for instance, for under-water work. Water containing 4 to 20 per cent of silicate of soda by volume causes a preliminary set in 2 hr. that prevents washing away by water. It injuriously affects the natural and gradual hydration, however, unless the sodium hydroxide, carbonate or sulphate is washed out by excess of water, which is difficult to do. Mixtures containing above 4 per cent of silicate show strong efflorescence, which is particularly marked with that made with 20 per cent aqueous solution of silicate. The silicate-of-soda-setting is at first due purely to double decomposition of sodium silicate and calcium hydroxide. If very strong silicate is used the mass stiffens so fast that it cannot be worked. This is true of all concentrations of 50 per cent or over.

There is one point that might be noted. For immediate immersion in running water silicate of soda acts

as a binder, while the particles of the cement form gelatinous colloids instead of being washed away. The soluble sodium salts are more or less eliminated and apparently normal concrete results. I have used glue solutions (3 to 5 per cent strength) with white Portland cement to secure very dense compositions. It is possible that the glue aids colloid formation, and protects the same against too rapid crystallization.

2. Oil Proof

(a) Several of the best known lutes I am placing under this category, although they might be classified elsewhere:

Good glue	2 parts by weight
Glycerine	1 " " "
Water	7 " " "

The glue is first softened by the water, then liquified by heat and the glycerine incorporated. This is a good lute to render corks vacuum tight, for stopping small leaks of almost anything except water and steam.

(b) The following has been found useful in laboratories and in the works for oil vapors:

Putty of molasses and flour.

(c) The next lute to be mentioned is one of the best known and most useful. The proportions given are those I have found satisfactory:

Glycerine	90 parts by volume
Water	10 " " "

To be made into a stiff putty with

Litharge	90 parts by weight
Red lead	10 " " "

It takes several hours to stiffen and about a day to set.

(d) Several cements of which silicate of soda is an active principle or the chief binding substance are as follows:

Silicate of soda (about 30 deg. Be.)

Whiting

Made into a stiff putty.

This slowly sets by drying if not by chemical action. If magnesium carbonate be used the setting is so quick that it is hard to use the mixture. If it is used, however, the silicate should be diluted to one-third to one-half normal strength. I do not recommend either of them.

(e) Barium sulphate is often used with silicate of soda. The silicate should be about 30 deg. Be. If the mixture is heated by a preliminary heating of the silicate or it is put in a hot place there seems to be some chemical reaction which aids in the setting.

(f) A very strong and ultimately hard cement or substance for a variety of purposes is made by incorporating glue with plaster of Paris. This will be described with other plaster plastics in Section 6.

3. Acid Proof

(a) The asphaltic preparations referred to in Section 1 are largely acid proof. Black putty, the formula for which was first noticed by me in a "Handbook of Chemical Engineering," by George E. Davis, is made by intimately mixing equal weights of China clay, linseed oil and gas-tar. The ingredients must be anhydrous, so it would probably be best to take a tar residuum or very soft pitch of thick, so-called, creosote oil. Rubber cements may have varied composition, but I will only refer to two which are, perhaps, extremes. If equal parts of fresh unvulcanized rubber are used the mass is so stiff that it would be probably used alone. If as much as four parts of linseed are used considerable filler can be incorporated and make a workable putty.

(b) Equal weights of rubber and boiled oil are taken; the rubber is first dissolved in carbon disulphide in the proportion of 4 c.c. carbon disulphide to

1 gr. of cut-up rubber. Boiled linseed oil is then mixed in, and the mixing is facilitated if the oil is warm. The solvent is generally not removed by evaporation until the paste is applied.

(c) The other formula, to which reference has just been made, differs in having four times as much boiled linseed oil and then fire clay or other filler, such as siliceous, is used.

Crude, finely cut rubber. 1 part by weight

Linseed oil, boiled..... 4 " " "

Fire-clay 6 " " "

(d) Melted sulphur with fillers of stone powder cement, sand, etc., are used. The following is used for hydrochloric acid vapors:

Rosin 1 part by weight

Sulphur 1 " " "

Fire-clay 2 " " "

Linseed oil (boiled) and fire-clay stand most acid vapors.

(e) According to Davis red lead and litharge in boiled oil stand acid vapors (even nitric acid).

Litharge 80 lbs.

Red lead 8 "

Flock asbestos 10 "

Fed into a mixer, a little at a time, with 6 qt. of boiled linseed oil.

There are numerous acid-resisting mixtures possible in which silicate of soda is used. This is possible, in spite of the strong basic character of silicate of soda, because the silicate is superficially changed to colloidal silica, which continues the cementing work, at first effected by the silicate of soda.

(f) Barium sulphate, powdered glass, China clay, etc., are used with silicate of soda slightly diluted with water. A strength of about 30 deg. Be. is close to what is best for the purpose.

(g) The following I have used with success for dilute hydrochloric acid:

White China clay 1 part by volume

Fine white sand, or powdered

quartz and sand 2 " " "

are mixed thoroughly and worked up with just enough silicate of soda, diluted with an equal volume of water to make a paste. This can be rendered more impervious to water by the judicious incorporation of organic colloids. If a little fine casein be incorporated with the silicate of soda in a mixer so that the mixture is quite smooth the mass will be better. About 5 per cent of fine, dry casein powder is added, based on the weight of silicate. If fresh milk curd can be used, corresponding to the same dry weight of casein and allowance is made for the water contained, a mechanical mixer may not be needed.

4. Chlorine Resistant

(a) The most reliable are made with Portland cement as chief ingredient:

Powdered glass 1 part

Portland cement 1 "

Silicate of soda..... 1 "

The last mentioned should be diluted considerably so as not to set too fast.

Portland cement quickly reacts with silicate of soda, but powdered glass and clay react more slowly with silicate of soda, but finally render the cement insoluble as regards its mass.

5. General Purposes with Plaster of Paris

This series of lutes and cements is highly important, and individual formulae will serve to prevent the escape of hydrocarbon and other gases in furnace work, as cements for mechanical purposes and as coatings, such

as plaster, when mixed with asbestos straw, plush trimmings, hair, etc.

(a) Soluble sulphates form double sulphates with calcium sulphate and with water. They set harder and are more impervious than calcium sulphate (plaster of Paris) alone. It is desirable not to take equal molecular quantities to form the full double sulphates, but about half of these quantities. Sodium, potassium and aluminum sulphates are used for this purpose.

(b) According to Sigmund Lehner, a little borax in the water used makes hard cements and regulates the setting: 12 volumes water to 1 volume saturated borax solution sets in 15-20 min. at 10 deg. C.; 8 volumes water to 1 volume saturated borax solution sets in 1 hr. The same author gives a formula credited to Viotti for a weatherproof plaster cement.

(c) One thousand five hundred grams of borax and 150 grams of magnesium oxide are melted together and powdered. This powder is then mixed with 75 grams of plaster of Paris. Borate of magnesium thus predominates and protects the plaster from being washed away by water.

6. Marine Glue

Standard preparation of this class of lutes, (which are applied to crevices, etc., hot, and get firm but not brittle when cold) is composed as follows:

Crude rubber	1 part by weight
Shellac	2 " " "
Pitch	3 " " "

The rubber is first dissolved in carbon disulphide or turpentine before mixing with the heated (not superheated) mixture of the other two. The advent of blown petroleum residuums has made it possible to make up hard but flexible compounds without rubber. Grahamite is a good base to which fluxes, such as these just mentioned or soft asphalts, are added.

7. Gasket Compositions

There are so many good gasket compositions on the market that I was on the point of omitting all reference to them. For factory work I have found no trouble in getting ropes of graphitized asbestos, rubber composition leather fibers cemented with rubber, etc., that are quite satisfactory.

In the laboratory one can generally make out for low temperatures and pressures by saturating heavy "kraft" wrapping paper with soft pitch, such as wood pitch for steam or with gelatine and glue (hectograph) composition for oils. For high pressures, slots filled with lead rings and a V-shaped rim to the lid are most satisfactory.

8. Machinists' Cements

A few words might be said here with reference to machinists' cement. These are the well-known red and white leads. The red lead is often diluted with an equal bulk of silica or other inert substance so as to make it less powdery on drying. The best way that I have found to accomplish this, however, is to add rubber or gutta-percha to the oil as follows:

Linseed oil	6 parts by weight
Rubber or gutta-percha..	1 " " "

The rubber or gutta-percha is dissolved in sufficient carbon disulphide to give it the consistency of molasses, mixed with the oil, and left exposed to the air for about 24 hr. The red lead is then mixed to a putty. Oxide of iron makes less brittle cements than red lead.

9. Leather Cements

As cements of this class are apt to be wanted by chemists sometimes, I quote from my paper in the *Transactions of the Engineers' Club of Philadelphia*, XXI, 4, 1904.

The following formulæ are given in the "Papier Zeitung," Vol. 18, p. 2618:

"(a) Equal parts of good hide-glue and American isinglass, softened in water for 10 hr. and then boiled with pure tannin until the whole mass is sticky. The surface of the joint should be roughened and the cement applied hot.

"(b) One kilo of finely shredded gutta-percha digested over a water-bath with 10 kilos of benzol, until dissolved, and 12 kilos of linseed oil varnish stirred in.

"(c) Seven and one-half kilos of finely shredded india-rubber are completely dissolved in 10 kilos of carbon disulphide by treating while hot, 1 kilo of shellac and 1 kilo of turpentine are added, and the hot solution heated until the two latter ingredients are also dissolved." Precautions against fire and vapors should be observed.

(d) Another one noticed in the "Journal of the Society of Chemical Industry":

Gutta-percha	8 ozs.
Pitch	1 "
Shellac	1 "
Olive oil	1 "

These are melted together.

10. Iron Cements

When iron in a fine state of division, as in fresh oil-free filings or cast-iron borings that have been powdered, is mixed with an oxidizing agent, such as manganese dioxide or a substance electro-negative to iron, such as sulphur, in a good conducting solution like salt or salammoniac, galvanic action sets in very rapidly, ammonia is given off (if salammoniac be used) and the iron swells, by forming iron oxide, and cements the mass together. It is best diluted with Portland cement. A formula which I give from memory is:

Iron filings	40 parts
Manganese dioxide, or flowers of sulphur	10 "
Salammoniac	1 "
Portland cement	20 to 40 "

Water to form a paste.

These cements are used extensively in foundries, etc.

I prefer manganese dioxide to sulphur as a negative element. The free carbon of cast iron that has been powdered is negative pole enough to react, but the use of manganese dioxide causes quicker action. If not diluted with cement they are apt to expand too much and bulge out from the hole or crevice in the iron.

11. Crucible Cements

(a) Mixtures of clay and borax in which the clay predominates. Silicate of soda and powdered glass or sand are the best known compounds for cementing lids on crucibles, etc. Sometimes the "iron cements" are used for such purposes, or iron filings and a little manganese dioxide are added to the above compositions for crucible cements.

(b) Probably the best known cement for graphite is fire-clay, which with water binds the graphite fairly well and itself stands high temperatures.

(c) In some cases it is desirable to have an all-carbon binder, and for this purpose tars or soft pitches are used. Very little binder must be used, however, or the material will crack when heated, as the carbonizing of the pitch shrinks the binder somewhat. Starch paste has been recommended for this purpose, but the shrinkage is greater and the binding is not as good.

(d) A strong, waterproof cement that will stand high temperatures may be made by mixing powdered silica or fine sand and powdered silica with a solution of magnesium chloride of about 10 per cent strength. This composition is applied as a putty and then painted

or soaked in a solution of silicate of soda of about 30 per cent strength. This forms magnesium silicate as a binding material for the silica.

13. Magnesia Composition for Furnaces, Etc.

Magnesia burned at incandescent heat or hard-burned, 80 per cent. Magnesia light burned (just sufficient to drive off carbon dioxide (dull redness), 20 per cent. The composition is made into a stiff putty with water and shaped as desired. The water must be driven off very slowly. A small proportion of good asbestos fiber may be worked in to keep from cracking.

14. Oxy-Chloride Cements

These are sometimes called stone cements and the only one of practical importance is that made with magnesium chloride.

If the magnesium chloride is quite pure, i. e. free from potassium or calcium chloride, the solution used need not be more than 18 deg. Be., but if commercial German magnesium chloride be used it requires a solution of 20 to 22 deg. Be. The magnesium oxide must be freshly burned at a dull red heat as the light oxide that is requisite for this cement readily absorbs carbon dioxide from the air and becomes unsatisfactory or of no use for making cement compositions. A diluent for the magnesium oxide is generally used, such as silica or wood pulp, ground wood, etc.

This communication is not offered as being an exhaustive treatment of the subject, but as an attempt at bringing together only tried or traceable formula for the making and using of lutes and cements.

Science and Aesthetics

From Dr. JOHN A. BRASHEAR's presidential address before the American Society of Mechanical Engineers (Dec. 7, 1915) we cull the following paragraphs:

"Dr. Maclaurin tells us a story of Matthew Arnold, the apostle of sweetness and light, in which he is made to say that when a candle burns the oxygen of the air combines with the carbon in the candle to form carbonic gas, *but who cares?* The story is told because it suggests an attitude to science that is far from rare, even among people of intelligence to-day. He recalls the poetic query of Keats when he writes of the rainbow: 'Do not all charms fly at the mere touch of philosophy? There was an awful rainbow once in heaven, we know her woof and texture. She is given in the dull catalog of common things. The complaint seems to be that science with its analysis of color robs us of the pleasing sense of awe and mystery, but if you dig deep you will find enough mystery left to satisfy the keenest yearner after half lights and the obscure. At best, science replaces one mystery only by another of grander order.'

"Now, leaning for a moment from the purely utilitarian side of science to the aesthetic, there comes a joy to the lover of the beautiful that cannot be expressed in words, for he sees in the color of an American Beauty rose the same light waves that tint yonder red star, whose light waves, coming to him at the rate of 180,000 miles per second, left it a thousand years ago. He listens to the varying bell tone of the swiftly moving locomotive and translate it into the motion of stellar worlds, whose distances have never before been measured by the most refined modern instruments.

"Does the photographic picture of your favorite landscape lose any of its beauty when you are told that during an exposure in your camera of only one-tenth of a second from forty to eighty millions of millions of light waves have hammered upon your negative tending to

shatter them to pieces or change their molecular arrangement?

"Maclaurin gives a charming illustration to help us better understand what it means when a ray of violet light impinges on our photographic plate for one-tenth of a second. 'Imagine you are watching a log floating near the seashore, and that it strikes against a pier as it rises and falls with the waves, say, once in six seconds. In order to correspond to the number of light waves in one-tenth of a second, the log would have to beat up against the pier for more than two million years.'

"But enough for the present of the aesthetic side of science, though it has beauties in its every phase, whether it be in the flower or in the rainbow—whether it be in the structure of glass from which the prism is made, or the story it tells of yonder far-off universe. But can we connect this science beautiful with our engineering problems? Why not?"

Analysis and Assay of Zinc Retort-Residue

The smelting of Western zinc ores leaves a retort residue which is sometimes valuable for its content of gold, silver, lead or copper, or some combination of these metals. It is customary to resmelt these residues in lead blast furnaces. In some cases the residues are handled by the company originally selling the zinc ore, and in others by the zinc-smelting company itself. In either event, the practice has brought new problems to the analytical chemist in determining the valuable constituents, on account of the large quantity of carbon left in the residue and the refractory character of the sintered material. In the early history of residue analysis, chemists found difficulty in obtaining concordant results and in checking each other, due largely to the fact that the methods applicable to ores were not wholly suited to retort residue, as well as to a lack of uniformity in the methods adopted. These difficulties have now been largely overcome, and we present some of the methods adopted at various places. Constructive criticism is invited in the hope of making the methods more exact and efficient.

Details of Analysis

The following methods are in use at the Hillsboro, Ill., plant of the American Zinc Company of Illinois:

Carbon.—Weigh 1 g. of the residue into a casserole, add 15 c.c. HCl and boil five minutes. Add 30 c.c. hot water, clean the casserole thoroughly and filter through a weighed filter, washing with hot water. Remove the filter and contents and dry at 100 deg. C. Weigh and ignite until all carbon is burned. Weigh the ash, and calculate carbon as the difference between the weight of the ash plus filter paper and the weight of dry carbon plus filter.

Zinc.—To the filtrate from the carbon determination, add 15 c.c. ammonia and 1 c.c. hydrogen peroxide, and boil until all peroxide is expelled. Filter and wash with hot water. Dissolve the precipitate in the original beaker with a little HCl and reprecipitate as before, filtering through the same filter. To the filtrate add 20 c.c. HCl, and if copper is present remove it by adding 10 g. test lead and boiling for ten minutes. Determine the zinc volumetrically by titration with standard solution of potassium ferrocyanide, using ammonium molybdate as indicator.

Iron.—Dissolve the precipitate, obtained by the above treatment, in the original beaker with dilute HCl (1:3). Wash and boil. When boiling hot add, drop by drop, a saturated solution of stannous chloride until the solution is clear. Cool and add 25 c.c. saturated

solution of mercuric chloride. Determine iron volumetrically by titration with a standard solution of potassium bichromate, using a weak solution of freshly prepared potassium ferrocyanide as indicator.

Sulphur.—Weigh 1 g. of the residue into a 50 c.c. crucible and mix thoroughly with 10 g. Eschka's mixture (two parts MgO , one part Na_2CO_3). Heat slowly over a Bunsen burner until all carbon is expelled, stirring frequently with a platinum rod. Dissolve the mixture in dilute HCl , add 1 c.c. hydrogen peroxide, boil and filter, washing the residue thoroughly. Precipitate sulphur as barium sulphate by the addition of barium chloride, and boil for five minutes. Allow to settle and then filter, wash, ignite and weigh as barium sulphate. The weight multiplied by 0.1375 gives the equivalent of sulphur.

Lead.—Weigh 2 g. of the residue into a 200 c.c. flask and add 10 c.c. HNO_3 , 6 c.c. HCl and 10 c.c. H_2SO_4 . Boil to white fumes, cool, dilute with 50 c.c. water, boil, filter and wash. Dissolve the lead sulphate thus obtained in a clean beaker with hot ammonium acetate, and after washing thoroughly add 20 c.c. of a 10 per cent solution of potassium bichromate. Allow to settle and then filter, washing thoroughly. Place the filter and lead chromate in a clean beaker, add 50 c.c. water and exactly 1 g. ferrous ammonium sulphate. Add 50 c.c. HCl and titrate the excess iron with standard solution of potassium bichromate. Lead equals 1.226 times the difference between total iron in 1 g. ferrous ammonium sulphate and the amount found by titration.

Copper.—To the filtrate from the above add an aluminium cylinder large enough so that one-third of its surface will not be immersed in the solution. Boil until all copper is precipitated; remove the cylinder, rinse thoroughly and dissolve the adhering copper into a clean beaker. If any copper remains behind, filter and add to that dissolved from the cylinder. Dilute the solution, add a slight excess of ammonia and titrate with standard solution of potassium cyanide.

Determination of True Silica

The exact determination of silica (SiO_2 , not insoluble) requires unusual precautions under ordinary circumstances, but seems to offer particular difficulty in retort residue. The method used at Hillsboro is as follows:

To 1 g. of the residue add 20 c.c. aqua regia and run to dryness. Bake in order to dehydrate soluble silica. Cool, add 15 c.c. HCl and boil five minutes. Dilute with 30 c.c. hot water, filter and wash. Place the filter and contents in a platinum crucible and burn off the carbon. Mix the ash with 10 g. Na_2CO_3 and fuse. When the fusion is quiet, cool and remove to an evaporating dish, preferably platinum, and dissolve the melt with water and HCl . Evaporate to dryness and bake until no odor of HCl can be detected. Add hot water and HCl and filter through an ashless filter, washing until the filtrate shows no chlorine. Ignite and weigh as SiO_2 .

At the Ohio & Colorado smelter, where retort residue is smelted, the procedure for silica is slightly different. One-half gram of the sample is mixed with 6 g. of sodium peroxide in a 20 c.c. nickel crucible, and covered with 2 g. sodium hydroxide (a stick about $\frac{3}{4}$ in. long). Fuse in an assay muffle at a faint red heat. The action once started is violent and soon complete. Allow the crucible to stand for three minutes at a temperature slightly above the melting point of the mixture, finally removing it to a casserole to cool. Cover with a watch glass, and cautiously fill the crucible with cold water. When the action ceases, fill the crucible again, after which the melt should be completely dissolved. Remove and carefully wash the crucible. Now add HCl until the solution clears. If black particles

are visible in a residue, the decomposition has been incomplete and the assay must be repeated. Evaporate to dryness, but avoid baking so hot that a black color appears. If the residue is a light brown, the operation has been properly conducted. Cool, moisten with 20-25 c.c. conc. HCl , add 100 c.c. water and boil. Filter through an ashless filter and wash free from chlorides. Dry, ignite and weigh as SiO_2 , doubling the weight to obtain percentage.

In one of the Denver custom laboratories the method is still more exact, special precaution being taken to prevent the loss of soluble silica. The weighed sample is treated with aqua regia and evaporated to dryness. A second similar treatment is given, and as the evaporation nears completion, a little HCl is added. When finally dehydrated, the residue is treated with dilute HCl , boiled and filtered. The filtrate is retained for further treatment. The insoluble thus obtained is fused in a platinum crucible with a mixture of sodium and potassium carbonate, cooled, dissolved in dilute HCl and twice evaporated to dryness. The residue, which is SiO_2 , is treated with hot water and HCl , boiled and filtered, combining the filtrate with that first obtained. The combined filtrate is now evaporated to dryness, taken up in dilute HCl and filtered. Additional SiO_2 , to the extent of from 1 to 2 per cent is thus obtained, and is added to the larger quantity, ignited and weighed.

Assay for Silver

At the Ohio & Colorado smelter the nitre-crucible assay is used, taking $\frac{1}{2}$ A. T. of the residue in a 20 g. crucible. The fluxing mixture is 20 g. soda, 4 g. silica, 35 g. litharge, and an amount of nitre determined from the following procedure: Determine the carbon in 1 g. of the residue by igniting in an assay muffle and weighing the ash, and from this figure determine the carbon in $\frac{1}{2}$ A. T. Compute the amount of nitre necessary to oxidize this amount of carbon to CO , and for purposes of the assay use this calculated amount of nitre less 2 g. It amounts usually to from 9 to 12 g. The fluxing mixture and residue are thoroughly mixed, covered with 10 g. soda and a teaspoonful of borax glass. Fuse slowly at a low heat for about half an hour, as the assay will boil over if the initial heat is too high. After the charge has settled quietly in the crucible, raise the heat as high as possible and pour. The resulting button is cupelled in the usual manner.

A very satisfactory method is one used at some zinc smelters and by certain custom assayers. The flux contains nitre in amount sufficient, as determined by experience, to give the right size lead button when $\frac{1}{4}$ A. T. of the residue is used. As the amount of carbon varies in the residue, it may be necessary to make an occasional preliminary assay and vary the amount of nitre according to the result obtained. Little or no trouble is experienced from boiling, and the method is reported to give entire satisfaction.

Purification of Water by Ozone.—To correct a misprint in our issue of Feb. 1, page 160, it should be stated that the cost of purification as carried out by the Baltimore County Water & Electric Company at the present time is less than \$2.00 per 1,000,000 gal. of water treated. Besides the aluminium electrodes and micanite dielectric tubes a feature of particular interest in the system is the aspirator tubes used for drawing the ozone through the generators and mixing the gas with the water. The system was developed by the chief engineer of the company, Mr. A. E. Walden. Mr. S. T. Powell presented an interesting paper on this system at the recent Baltimore meeting of the American Institute of Chemical Engineers.

The Use of Low-Grade Phosphates*

BY JAMES A. BARR

When phosphate mining operations first commenced in Tennessee the loss of both high- and low-grade material was large, because of the crude hand methods employed. Practically all rock smaller than 2 in. was thrown back into the pits and covered up with the overburden of subsequent openings.

With the advent of mechanical washers and other mining machinery, together with the abolishing of the contract system, the waste has been steadily diminished, until at present only the finest sand is being rejected; and even this is not lost, for in the majority of cases the water, slime and sand from the washers are run into large settling ponds where practically all of the phosphate-bearing material is caught and stored for future use, or until it is profitable to ship lower grades.

The latest equipment used to recover the fine and lower grades of phosphate sand includes Dorr thickeners, settling tanks, Dorr classifiers and settling ponds served by locomotive cranes with clam-shell buckets, making it possible to save material averaging as fine as 200 mesh. To attempt saving finer material would necessitate a different type of drier, which might be patterned after the multiple-deck roasters.

The present tailing runs from 15 to 25 per cent of available phosphate, which, however, as mentioned before, does not represent a total loss to possible future operations. The demand of the consumer is the greatest factor in regulating the recovery at present.

In the mining of blue rock, which does not require washing treatment, the main waste material is the capping of low-grade kidney formation, generally used for backfilling of the rooms.

By reason of the introduction of improved methods in the early stages and the re-mining of territory skimmed over at the start, at the present time the net result of all operations is a comparatively small loss.

One of the largest temporary losses in the industry occurs in the Florida pebble district, where the recovery of phosphate runs about 25 per cent. The loss is classed as temporary because most of the tailing has been collected in ponds and piles, where it may be reclaimed in the future should developments or improved processes warrant.

In cleaning the Florida pebble phosphate, aside from the elutriation of the clayey binder and strata that sometimes contaminate the rock, the main operation is that of sizing, by which the large phosphate grains are separated from the smaller silica sand. This results in the loss of all the fine phosphate along with the silica. Owing to the similarity of the two in specific gravity, no mechanical process has been developed as yet to effect a further saving.

PROBLEMS AWAITING SOLUTION

As the problem now stands, the development of some concentration process is required to effect a further recovery of the low-grade phosphate in Tennessee and Florida, where the consumers demand a high-grade product.

Taking 68 per cent tricalcium phosphate as the present minimum average grade for Florida pebble and Tennessee blue rock, and 72 per cent for the Tennessee brown rock, it will be seen that the development of such a concentration process is a much needed step in the conservation of the phosphate resources, for by its introduction the commercial limits for use in complete fertilizers could be reduced to 60 per cent and possibly 50 per cent tricalcium phosphate.

In the event of low grades of phosphate becoming commercial products, 20,000,000 tons would become available within a 50-mile radius of Mount Pleasant, Tenn., alone, and perhaps 100,000,000 tons of rock, especially if phosphatic limestone is taken into account. These figures are not claimed to be precise, but are given to indicate that the available phosphatic resources have, so to speak, merely been scratched.

It would seem that the most feasible means for making low-grade phosphate commercially available lies in the development of a smelting or electrometallurgical process whereby the phosphorus content of the rock would be rendered available (soluble) directly and without the introduction of a diluent, as in the manufacture of acid phosphate by the sulphuric acid method. By such a direct conversion, a 60-per cent rock would serve the same purpose as a 72 to 75-per cent rock with the sulphuric acid method.

Along these same lines a combination process may be developed whereby low-grade phosphate and an insoluble potash feldspar or similar potash mineral may, by heat or other treatment, be rendered available for use as a commercial fertilizer. The European war has brought out the importance of such a discovery.

Again, there might be developed another combination process whereby ammonia phosphate could be made directly, as cyanamid is now manufactured with the aid of an electric furnace.

DIRECT USE OF PHOSPHATE ROCK AS FERTILIZER

The greatest possibility of using low-grade phosphate lies in the direct application of finely ground rock to the soil in the raw state, allowing the acids of nature to convert it into soluble forms. One authority on farm fertilizers has said that in the majority of cases a mixture of raw ground phosphate with stable manure makes one of the best fertilizers.

The difficulty with the ground phosphate trade has been that the fineness of grinding was not such that a sufficient percentage of the commercial product became available within any reasonable time. When the grinding industry was new, the fineness was generally 90 per cent through 80 mesh, while now it is 90 per cent through 100 mesh, or even finer. The impalpable powder gives effective and immediate results; therefore the future extension of this particular phase of the phosphate industry will be aided greatly by finer grinding.

Another available source of phosphorus is basic slag from steel manufacture. The United States Steel Corporation has erected a plant in Alabama to prepare such slag for fertilizing purposes and has placed the product on the market.

This form of fertilizer has been successfully used in Germany.

An average grain crop requires and takes about 15 lb. of phosphorus per acre from the soil in which it is grown. This phosphorus must eventually be replenished, for with a meager amount of phosphorus in the soil the crops are poor, and with none the harvest is nil. The majority of farmers fail to replenish the soil with the elements taken out by the crops, and at no very distant time they will be drawing heavily on our phosphate resources.

In view of this, the use of the lower grades is certain to become common.

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Lead and Zinc Smelter to Reopen.—The lead and zinc smelter in Webb City, Mo., will be reopened shortly and will be operated by the Picher Lead Co. of Joplin. This smelter has been idle for several years and when in operation will employ about 100 men.

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The Hydrometallurgical Treatment of Complex Gold and Silver Ores

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BY G. H. CLEVENGER

The term "complex ore" has never been clearly defined, nor is it probable that it ever will be. If defined upon the basis of the ability to obtain a high extraction, an ore which could be treated at a profit and a high extraction realized could be called a *simple ore*, no matter how complicated the process for realizing this end might be.

Then, again, the classification might be based upon the nature of the process necessary for the satisfactory treatment of the ore; thus an ore which required a complex process or combination of processes might be classified as a *complex ore*, while an ore with which a simple process sufficed might be called a *simple ore*. The latter suggestion seems to be the more logical basis for a classification. But it would be difficult if not quite impossible to draw the line as to where a process ceased to be simple and where it became complex, as this would be largely a matter of personal opinion upon which there could be no general agreement.

Despite the difficulty of satisfactorily defining a "complex ore" there is a constant effort being made to treat ores by hydrometallurgical methods which have previously resisted such attempts, and metallurgists are also constantly endeavoring to develop more simple and direct processes of treatment which will either result in a higher extraction, lower working costs, or both.

Historical

The present status of the hydrometallurgy of gold and silver is perhaps best understood by going back to the beginning of hydrometallurgical practice and briefly tracing the various developments down to the present day.

The oldest hydrometallurgical process, if such it really could be considered, was the simple operation of panning in water a gold-bearing sand or ore which had been crushed between stones. This was soon supplemented by the passage of the finely ground ore with water over the hair side of the skins of wild animals.

The next development was the *early Roman amalgamation process*, first described in Pliny,¹ which was conducted by agitating the pulverized ore with mercury and water in earthen vessels. Since this process was only effective for the recovery of metallic gold or silver from simple ores it was but natural that the *early European amalgamation process*,² capable of treating more complex ores, particularly those of silver, should be developed. The prominent features of this process as ordinarily carried on was the grinding of the ore in a stone mill with water, mercury, salt, and some compound of copper. At times other reagents were added, but they were not essential. Although this process was in use in various parts of Europe at a much earlier date, it was first described by Biringuccio³ in 1540.

Bartolme Medina introduced the *Patio*,⁴ or, as it was sometimes known, "*Mexican Amalgamation Process*," at Pachuca, Mexico, in 1557. The finely ground ore, moistened with water, was mixed with mercury,

copper sulphate and salt on large stone-paved areas (patios) by the treading of horses or mules. Since all the mercury at this time came from Europe, it seems probable that Medina had as a basis for the development of this process a general knowledge of the European process of amalgamation.

Be this as it may, great credit was due him for this new and novel metallurgical process which made possible for the first time the treatment of large lots of ore by a hydrometallurgical process at a reasonable working cost. So thoroughly did he adapt the general principles of amalgamation to the special conditions met with in Mexico that few improvements were ever made in the original process, which held the field for the treatment of silver-gold ores in Mexico until within recent years, when the cyanide process, capable of giving a higher extraction of the gold and silver, was developed to the point where it could be more economically applied than the Patio process.

The *Cazo* or *Fondo process* was invented by the priest Barba,⁵ residing in Bolivia, while experimenting as an alchemist in 1609. This process comprised stirring the finely ground ore with water, mercury and salt in a copper kettle heated over a fireplace. Until about 1793 the Fondo process was used in South America and Mexico with but few variations from the method as originally described by Barba. At about this time a larger vessel having a copper bottom and wooden sides, in which the stirring was done by mule power, came into use. This was known as the *Fondon process*.⁶

The *Tina process*,⁷ employing an iron-bottomed wooden vessel, in which the ore was ground in water and amalgamated with mercury, was used at Kongsberg, Norway, for treating native silver ores. A modification of the Norwegian Tina process⁸ was also used at a later date in Chile for treating simple ores.

The chloridizing roast for silver ores, introduced by Born,⁹ was first combined with the Cazo process¹¹ at Schemitz, Hungary, in 1786. Barrel amalgamation¹² in combination with the chloridizing roast was first introduced at Hålsühütte, near Freiberg, in 1790.

The *Washoe process*,¹³ developed through the combination of the California stamp mill with an elaboration of the Norwegian Tina for fine grinding and amalgamation (pan) and the chemicals of the Patio process, was introduced for the treatment of Comstock ores in 1860. This amalgamation process, adapted to American conditions, rapidly assumed the same position in the United States for the treatment of silver-gold ores as was occupied by the Patio process in Mexico for the treatment of the same class of ores.

A later development when treating complex ores was to give a chloridizing roast preceding grinding and amalgamation in the pans. This was known as the *Reese River process*.¹⁴

The *Kröhnke*¹⁵ process of barrel amalgamation was introduced into Chile in 1862, but had a limited use. The date of the first use of amalgamated copper plates

¹ Naturalis Historiae. Lib. XXX. Cap. VI, sect. 22. Translation—Metallurgy of Silver and Gold, John Percy, London, 1880, p. 559.

² De Re Metallica, Georgius Agricola. Hoover's translation from the first Latin edition of 1556. Book VIII, pp. 293, 298.

³ De la Pirotechnia, per Vannoccio Biringuccio. Senesce, Ventia, 1540, Lib. IX, Cap. XI, fol. 142. Translation—Metallurgy of Silver and Gold, John Percy, London, 1880, pp. 560, 561.

⁴ Mexico. H. G. Ward, London, 1829, pp. 196, 199.

⁵ The Patio Process for Amalgamation of Silver Ores, by Manuel Valerio Ortega. Trans. Amer. Inst. Min. Engrs., Vol. XXXII, pp. 276, 285.

⁶ Arte de los Metales, antes cit. lib. III, cap. 16. Translation, Metallurgy of Silver and Gold, John Percy, London, 1880, p. 563.

⁷ Laur, Annales des Mines, 1871, Sixth series, pp. 216-236. Also Metallurgy of Silver and Gold, John Percy, London, 1880, pp. 661, 665.

⁸ Gröndlicher Unterricht, Schlüter, pp. 122 et seq. Translation, Metallurgy of Silver and Gold, John Percy, London, 1880, pp. 565-567.

⁹ Metallurgy of Silver and Gold, John Percy, London, 1880, pp. 567-573.

¹⁰ Handbook of Metallurgy, Carl Schnabel. Translation by Henry Louis, London, 1898, p. 688.

¹¹ Loc. cit.

¹² Ibid. p. 689.

¹³ U. S. Geological Exploration of the Fortieth Parallel. Mining Industry, James D. Harpe. Treatment of Comstock Ores, pp. 194, 272. Chemistry of the Washoe Process, pp. 273, 293.

¹⁴ The Reese River Process, The Metcannon Mill. R. W. Raymond. Mining Statistics West of the Rocky Mountains (1870), pp. 732, 740.

¹⁵ Metallurgy of Silver, by H. F. Collins, London, 1900, pp. 69-72.

as now used for the treatment of simple gold ores is not definitely known, but it seems probable that it began by supplying the inside of the mortar with copper plates, suggested, no doubt, by the use of the copper kettle in the Fondo process; this was followed by the use of plates outside of the mortar. Outside plates were in use as early as 1856¹⁶ at Grass Valley, California. Previous to this the metallic gold was collected upon the hairy side of the skins of animals, blankets or other rough surfaces.

The *Batopilas*¹⁷ process of amalgamation in pans with cyanide solution was described in 1911. The *Nipissing*¹⁸ process of amalgamation in a siliceous-lined tube mill with very strong cyanide solution was introduced early in 1911. The processes so far considered were all amalgamation processes. In 1848 the *Plattner chlorination process*,¹⁹ the earliest lixiviation process, was introduced. In this process an oxidizing roast of the ore preceded its treatment with chlorine gas. Through the suggestions and work of a number of men, the more modern process of *barrel chlorination*²⁰ was evolved in 1890. This process was more suitable for the treatment of large tonnages of ore than the Plattner process. *Vat chlorination*²¹ was the latest development in gold processes employing chlorine as a solvent.

A silver lixiviation process based upon the chloridizing roast of the ore followed by leaching with a solution of sodium hyposulphite was introduced in 1858 by von Patera.²² This was followed in 1860 by the proposal of Kiss²³ to use the calcium salt rather than the sodium salt on account of the supposed greater solubility of gold in calcium hyposulphite. In 1884, Russell²⁴ introduced the use of an extra solution of sodium-copper hyposulphite and sodium carbonate for precipitating the lead.

The *Augustin*²⁵ and the *Zierogel*²⁶ processes, introduced in the 40's, were used in a limited way almost exclusively for the treatment of matte. However, the recent application of the Augustin process²⁷ in connection with blast roasting for the treatment of low-grade complex silver ores containing lead and copper is worthy of note.

The first proposal for the treatment of gold and silver ores by cyanide solutions was made in 1867 by Ray,²⁸ although *Elkington*²⁹ had found in 1840 that gold was soluble in cyanide solutions with the aid of electricity, and *Bagration*³⁰ had discovered in 1842 that gold was soluble in cyanide solutions without the use of electricity. *MacArthur and Forrest*, in 1886,³¹ developed a process employing dilute solutions of cyanide, and zinc

precipitation. About the same time *Siemens*³² developed a process employing very dilute cyanide solutions and electrolytic precipitation.

It has required almost thirty years and the work of many men to bring the cyanide process to its present high state of perfection. Originally the cyanide process was only considered generally applicable to the treatment of simple gold ores and on account of the lack of suitable means for treating the slime high extractions were the exception rather than the rule, so that the cyanide process did not at once become a serious competitor of the older processes. The Plattner chlorination process for limited amounts of high-grade gold concentrate and the barrel chlorination process for large tonnages of siliceous gold ores continued to hold the field for the treatment of complex gold ores, and plate amalgamation with or without concentration for simple gold ores. The Patio amalgamation process in Mexico, and the Washoe amalgamation process, and to a less extent the hyposulphite lixiviation processes in the United States, continued to hold the field for treating silver-gold ores.

Cyanidation was first used to supplement the recovery made from gold ores by plate amalgamation. With the introduction of fine grinding and the various types of slime filters, it became a formidable rival of the older processes of amalgamation and chlorination for the extraction of both gold and silver. As the operation of the process became better understood, it gradually displaced the Patio process in Mexico, and the Washoe and chlorination processes in the United States. To-day all of the older processes of amalgamation, with the exception of plate amalgamation and the Nipissing process, are obsolete. The same may be said of chlorination, which made its last stand in treating the Cripple Creek telluride ores. The hyposulphite silver leaching processes long since became obsolete without ever becoming an important factor in ore treatment.

The cyanide process, with the exception of plate amalgamation and the Nipissing process, therefore, at the present time entirely holds the field for the hydrometallurgical treatment of gold and silver ores. For the purpose of discussion in this paper, amalgamation is considered an accessory operation. The advantage of treating both gold and silver ores by the same process is apparent. Silver was not recovered in the chlorination process and, if present to an appreciable extent, interfered with the gold extraction through the formation of insoluble silver chloride. Attempts to recover the silver by a subsequent treatment with sodium hyposulphite solution did not prove satisfactory. The silver amalgamation and lixiviation processes did not recover a high percentage of the gold and left much to be desired in the recovery of the silver. Unfortunately, gold and silver do not occur in ores in the sharply defined lines drawn at times by the limitations imposed by certain processes of ore treatment. The cyanide process being both a gold and a silver process, has the necessary flexibility regarding the recovery of the two metals from the same ore.

Preliminary or Accessory Operations

In order to properly consider the preliminary or accessory processes or operations which are available for use in conjunction with the cyanide process for increasing its effectiveness, it will be necessary to return to certain of the earlier processes and consider the function of certain of these operations as carried on in them.

The *oxidizing roast* was first applied as a preliminary operation with the old Plattner chlorination process for

¹⁶ The writer has corresponded with R. W. Raymond, the late S. B. Christy, and many others familiar with early metallurgical development in the United States, in a vain endeavor to ascertain where and by whom amalgamated copper plates were first used in the recovery of gold. Mr. W. L. Oliver has informed me that amalgamated copper plates were in use as early as 1856 at Grass Valley, California, U. S. A.

¹⁷ The Milling and Batopilas Native Silver Ores, Walter M. Brodie, The Mexican Mining Journal, Vol. XII, pp. 21, 23.

¹⁸ Nipissing High Grade Mill, R. B. Watson, Engineering and Mining Journal, Vol. 94, pp. 1077, 1080.

¹⁹ Metallurgy of Gold, by T. R. Rose, London, 1906, pp. 239, 256.

²⁰ The Present Development of the Barrel Chlorination Process, by John E. Rothwell, Mineral Industry, Vol. V, pp. 261, 284.

²¹ The Chlorination of Gold Ores at Mount Morgan, Queensland, E. W. Nardin, Proc. Inst. Civil Engrs., Vol. CXLII (1900), pp. 297, 307.

²² Handbook of Metallurgy, by Carl Schnabel, Translation by Henry Louis, London, 1898, pp. 718, 733.

²³ Ibid., pp. 732, 733.

²⁴ The Lixiviation of Silver Ores with Hyposulphite Solution, by Carl A. Stetefeldt (Second Edition). The whole work deals with the Russell process, or closely related matter.

²⁵ Handbook of Metallurgy, by Carl Schnabel, Translation by Henry Louis, London, 1898, pp. 708, 718.

²⁶ Ibid., pp. 740, 749.

²⁷ Chloridizing Leaching at Park City, Utah, by Theodore P. Holt, Trans. Amer. Inst. Min. Engrs., Vol. XLIX, pp. 183, 197.

²⁸ U. S. Patent No. 61,866, 1867.

²⁹ British Patent No. 8447, 1840.

³⁰ On the Property with Potassium Cyanide and Ferrocyanide Possess of Dissolving Metals, by Prince Pierre Bagration. Bul. de l'Acad. Impl. de St. Pet. (1843), II, p. 136.

³¹ British Patent 14,174, 1887.

³² Electrical Precipitation of Gold, by A. von Gernet. Proc. Chem. and Met. Soc. of Africa, Vol. I, pp. 28, 30.

gold. Roasting was absolutely essential to the successful operation of all the chlorination processes. The oxidizing roast should never be used in conjunction with any process for the recovery of silver, on account of the fact that it renders a large proportion of the silver refractory to all known hydrometallurgical processes, including the cyanide process.

The reactions occurring during roasting and the final chemical combination, or physical change of the silver existing in an ore at the end of the operation, have never been determined. This is a matter which is well worth careful investigation, as it appears that we have the same phenomenon to deal with in the treatment of certain naturally occurring oxidized ores of silver, particularly those containing oxidized manganese minerals. My own researches have led me to believe that the silver is not in combination with manganese, but that probably the oxides of manganese have exerted an influence upon the occurrence of the silver through their behavior as oxidizing agents. Certain silver ores containing the oxides of manganese are not refractory to cyanide treatment, but this fact in no way controverts the above theory.

The oxidizing roast as practised with the chlorination process is still employed in conjunction with the cyanidation of certain of the higher-grade sulphide and sulpho-telluride gold ores. It is significant that but little of the small proportion of silver which these ores generally contain is recovered during cyanidation. Several hundred tests made under the writer's direction have indicated that the raw sulpho-telluride ores (containing approximately 1.0 oz. of gold per ton) of the Cripple Creek district, with certain exceptions, will yield almost as high an extraction when ground very fine and given a long period of agitation as when treated by the common practice of roasting, followed by regrinding and cyanidation. The raw ore under the above conditions also yields a quite good extraction of the silver which is invariably below 1.0 oz. per ton. Notwithstanding this fact, the roasting process so far as we now know, under the conditions of cheap fuel and a roasting cost of 50 to 60 cents per ton, still holds the field for the following reasons: It is not necessary to grind so fine; the extraction is a matter of hours rather than days; the cyanide consumption is less and the solutions are less likely to become foul. However, investigation is constantly going forward in this direction, and it would not be surprising if raw treatment would eventually win out.

A recent development in the roasting of ores preliminary to hydro-metallurgical treatment is the application of blast roasting or continuous suction roasting machines of the Dwight-Lloyd type. This bids fair in certain cases to meet all the requirements of roasting and to reduce the cost of the operation materially.

The thoroughness of the roast determined whether the results were good or bad in the chlorination process and, while this is less true in the cyanide process, yet proper roasting is of prime importance if the best results are to be realized. It seems probable that careful investigation of the whole problem of roasting would eliminate the irregularities which sometimes arise. The oxidizing roast is only applicable to gold ores, and then only when the results are sufficiently improved, as regards extraction or costs, to justify its use.

The chloridizing roast, introducing salt during the roast, was first applied in connection with the Fondon process, and later became quite generally used with the barrel amalgamation process, the Washoe process and the silver lixiviation processes for treating refractory ores. The chloridizing roast has never been favored for gold ores on account of the high volatilization losses;

in fact, this is also its weakest point with silver, since silver chloride is quite volatile. It has been used at times in conjunction with the cyanide process, but its use in this connection has entirely passed out. It is claimed that volatilization of the silver is entirely under control in the newly-proposed system of blast and suction roasting. One possible application of the chloridizing roast under favorable conditions is in connection with the treatment of the so-called refractory manganese-silver ores, as most of the silver is converted into readily soluble silver chloride.

The losses of gold and silver occurring during roasting in a well-regulated plant have never been accurately determined, and, indeed, it would be a most difficult thing to do. Although such losses may be small, they constitute a factor which cannot be ignored.

Water concentration was applied in conjunction with many of the earlier processes, as, for example, the Patio and Washoe processes. It was early introduced, following simple plate amalgamation, for the purpose of augmenting the recovery from gold ores. Eventually all the tailing from the modern barrel chlorination plants were concentrated before being discarded. Concentration is a valuable adjunct of the cyanide process and has been practised both when crushing in water and when crushing in solution.

Generally the operation precedes cyanide treatment, on account of being more conveniently applied at this point, but in many cases it would be advantageous if it were feasible to have it follow cyanide treatment. When it precedes cyanide treatment, a considerable proportion of the readily soluble gold and silver may be removed in the concentrate, when it might be more advantageous to recover them as bullion. In the case of low freight rates and favorable smelter contracts this may be an advantage rather than otherwise; but for the majority of plants the more gold and silver turned out as bullion the better. Therefore, the ideal practice in most cases would be to recover all the gold and silver possible as bullion by the cyanide process and then concentrate the tailing to recover as high a percentage of the remaining gold and silver which had escaped dissolution as feasible. Obviously there are many cases where the percentage of extraction of gold and silver from the residue leaves no margin for concentration.

At times concentration can be introduced into the cyanide flow sheet to advantage for the purpose of removing the minerals which are difficult, if not impossible, to treat by the regular milling scheme, so that they may receive the special treatment necessary without having to incur the expense of subjecting the whole tonnage to the special treatment made necessary by a comparatively small proportion of refractory minerals. On the other hand, the introduction of concentration adds to the first cost of the plant and the complexity of its operation, so that these disadvantages must be carefully weighed against the advantages which are likely to accrue.

Chemical reduction is one of the latest developments in preliminary treatment and was, therefore, not used in conjunction with any of the earlier processes. Such a process is most feasible when carried on in an alkaline solution, as acids attack the gangue of most ores. Reduction may be accomplished through the use of dilute caustic soda solution with aluminium or zinc, or through electrolysis in a suitable solution by bringing the ore to be reduced into intimate contact with the cathode.

The only commercial application of reduction is at the Nipissing low-grade mill, where caustic soda and aluminium are used for converting silver sulphide and sulpho-antimonide minerals into metallic silver prior to

cyanidation. This preliminary treatment lessens the period of agitation necessary with cyanide solution.

Many experiments involving the preliminary reduction of telluride gold ores in caustic soda solution with aluminium and zinc, as well as cathodic reduction in both caustic soda and salt solution, have shown that with cheap fuel and efficient roasting this form of preliminary treatment would present no advantage. The gold telluride compounds are in general more difficult to reduce than the sulphide and sulpho-antimonide silver minerals.

Amalgamation, particularly plate amalgamation, is an important preliminary treatment with gold ores which contain any considerable proportion of readily amalgamable gold. In fact, in certain cases where a considerable proportion of the gold occurs native, the bulk of the extraction may be effected by amalgamation. However, the cyanide process is necessary for recovering the portion not recovered by amalgamation.

There is considerable difference of opinion among metallurgists regarding the extent to which amalgamation should be applied in hydro-metallurgical work. Those having the extreme point of view maintain that with sufficiently fine grinding to bring all the gold or silver to the degree of subdivision necessary for rapid dissolution, amalgamation may be dispensed with and the whole of the gold recovered by cyanidation. This can be done in certain cases, even with silver ores where a considerable weight of metal is involved, but it means a higher cost for grinding and generally also a higher cost for cyanide treatment and, therefore, may not be so profitable as coarser grinding and amalgamation followed by cyanidation.

Special types of amalgamation, such as the tube mill amalgamation practised at the Nipissing mine at Cobalt, Ontario, Canada, becomes absolutely necessary in the case of the very high-grade silver ores treated in this district which contain a large proportion of native silver, or closely allied minerals.

Flotation, the most recent development in ore dressing, which has become such an important factor in the recovery of the rare metals from their ores, is becoming a valuable adjunct to the cyanide process in connection with the treatment of the precious metal ores. Recently very good experimental results have been obtained upon refractory manganese-silver ores by giving a preliminary sulphidizing treatment followed by flotation. Flotation in alkaline solutions is also a recent development which promises much.

The data now available indicate that flotation may be used prior to cyanidation for removing minerals interfering with cyanide treatment, such as the sulphide copper minerals or such minerals as the tellurides and certain silver minerals which might be more advantageously removed in this way than decomposed and dissolved by cyanide. In most cases the tailing from flotation appears to be amenable to cyanide treatment, but the concentrate is not, even though there be no refractory mineral present. Gold concentrate is amenable to cyanidation after roasting, but silver concentrate is not on account of the refractory combination of silver formed by the oxidizing roast. Metallurgists are at work upon this problem and it is quite possible that a solution will be found in the near future.

The treatment of the tailing from cyanidation is a most attractive field, particularly since flotation in alkaline solutions has become possible. So far flotation has not been accomplished in cyanide solutions. Another very attractive field is the direct treatment of very low-grade ores which would not pay to cyanide. In many such cases a high extraction could be obtained, the tailing rejected and the concentrate cyanided or

shipped. This proposal is, of course, made upon the assumption that certain of the difficulties which now stand in the way of treating flotation concentrate will be overcome.

Important Factors in the Operation of the Cyanide Process

Inasmuch as the cyanide process is of vital importance in the present-day hydrometallurgy of gold and silver, a discussion of the more important controlling factors of the process is in order.

The degree of comminution of the ore is one of the most important factors, particularly in the treatment of silver ores. The purpose of grinding is to free the gold and silver minerals from the inclosing gangue and to reduce the mineral particles to such a size that they are readily dissolved. Grinding should be carried on in such a manner as to waste as little power as possible in grinding the worthless gangue and still fulfill the above named conditions to the fullest extent possible, since the less the mineral is protected by the gangue and the greater the surface of the mineral exposed to the solution, the more rapid the rate of dissolution.

It then follows, for example, in the case of certain silver ores, that while fine grinding may not produce any greater ultimate extraction, yet in general it will materially reduce the time of treatment necessary. But this advantage is not always realized without the disadvantage of greater consumption of cyanide arising, since finer grinding not only causes a greater surface of the minerals containing the precious metals to be exposed to the solution, but also a greater surface of those minerals, if present, which may act as cyanicides. Careful correlation of the time of treatment with degree of comminution may serve to minimize this difficulty.

Selective grinding whereby the heavy mineral particles are ground finer than the lighter particles of gangue takes place automatically to a greater or less degree in closed circuits where hydraulic or mechanical classifiers are employed so that actually in the majority of plants the heavy mineral particles are ground finer than the gangue. The additional cost of finer grinding, together with the attendant disadvantages which may arise, must in each case be carefully weighed against the additional extraction possible, or the decreased time of treatment necessary to obtain a given extraction.

The concentration of the solution of cyanide is a vital point. In general, the stronger the solution, within certain fairly well defined limits, the more rapid the dissolution, and, furthermore, the less the interference of a given percentage of impurity which might be present in solution. On the other hand, a greater proportion of impurity may be dissolved by the stronger solution. In the case of a plant which is operating at forced capacity a stronger solution may be used to advantage in order that the maximum extraction may be attained under this condition of operation. Stronger solutions may result in increased cyanide consumption, although the magnitude of this loss in a properly operated plant is not so great as has been supposed.

However, in a plant where there is considerable mechanical loss of solution the additional cyanide loss would prove an important factor. For this reason a strong solution is not generally favored when continuous decantation is used. The tendency in some cyanide plants has been to use a lower concentration in cyanide than that capable of giving the highest economical result. This probably is through the fear of excessive cyanide loss.

The alkalinity both as regards the kind of alkali and its concentration is perhaps only second to the concen-

tration of the solution in cyanide in importance. The effective alkalis are the alkaline hydroxides, the most available being caustic soda and lime. Lime in contact with the solution becomes calcium hydroxide, slightly soluble, but sufficiently soluble to be effective as an alkali in cyanide treatment. Lime in the majority of localities is much cheaper than caustic soda and, fortunately, is in the majority of cases the most satisfactory alkali to use. Many of the impurities which form soluble sodium salts form with calcium insoluble compounds which are eliminated with the tailing, thereby maintaining the solution at a higher degree of efficiency. There is evidence to indicate that when certain antimonial minerals are cyanided caustic soda may prove the more satisfactory alkali; this, however, is not definitely proved, and most certainly is not true in all cases.

The concentration of alkali, or as it is usually termed the protective alkali, may vary from practically 0 to 100 points.* At the Homestake a very low alkalinity is conducive to the best extraction, while in treating raw Cripple Creek ores a rather high alkalinity, employing lime, results in the highest extraction and the lowest consumption of cyanide.

Dilution or ratio of solution to dry ore in the pulp undergoing treatment is generally recognized as a factor to which proper attention must be paid if the highest extraction is to result. If a higher dilution is used than is necessary the capacity of the plant is cut down, and, on the other hand, if the dilution be too low the maximum extraction is not attained. It is quite impossible to give general figures for minimum dilution as these figures vary for different ores. In general, lower dilutions can be used with gold ores than with silver ores, probably on account of the greater weight of metal to be dissolved in the latter case. Other conditions being equal, it appears that lower dilutions can be used with the Pachuca agitator than with the mechanical agitator on account of the greater proportion of air brought in intimate contact with the pulp.

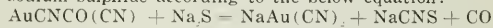
The time of treatment depends upon the character of the silver and gold minerals and upon their degree of comminution, and, as previously pointed out, also upon the concentration or strength of the solution in cyanide. It therefore follows that finer grinding, or increase of the cyanide concentration of the solution, or both, will in general result in reducing the time of treatment necessary. In cases where the cost of power is high, and as a consequence the cost of fine grinding would be excessive, the ore may be ground to the point where the minerals are liberated from the gangue and then separated into sand and slime, the slime being treated by agitation followed by either decantation or filtration. The sand containing the coarse mineral particles requiring a long period of contact with the solution for dissolution can be given the long period of contact necessary at a reasonable cost by leaching. Cases of this kind clearly indicate where combined sand and slime treatment can be employed to advantage.

The method of precipitation employed, assuming equal efficiency as regards the precipitation and recovery from solution of the precious metals, may exert an important influence upon extraction, either through introduction of the precipitant used into solution or its failure to precipitate certain interfering elements. For example, zinc in the presence of arsenic may interfere in the treatment of certain ores. If aluminium precipitation is used the difficulty is overcome through

the elimination of zinc. When copper reaches a certain concentration in solution difficulties arise with both extraction and precipitation. Neither zinc nor aluminium precipitate copper to any extent, hence if copper is to be removed from solution electrolytic precipitation must be used.

Carbon, which at times occurs in gold and silver ores, may occasion difficulty in cyanidation. It has been generally assumed that carbon occurs in gold and silver ores in the form of graphite, but the evidence available by no means supports this view in all cases. The two extremes of carbon as regards its behavior in cyanide solutions are graphite and charcoal. Graphite is dense and does not possess pores, therefore cannot occlude gases, while charcoal is porous and has the property of occluding relatively large volumes of gases. Graphite does not precipitate gold and silver from cyanide solutions while charcoal does. Intermediate between these two extremes are various forms of carbon which will precipitate gold and silver to a greater or less extent.

Feldtmann²² has shown that the graphitic or carbonaceous schist from the mines of West Africa will precipitate gold from cyanide solutions roughly in proportion to the carbon content or the schist. Gold so precipitated is not soluble to any appreciable extent in fresh cyanide solution, but is soluble in sodium sulphide solution. He thinks that the compound formed is possibly carbonyl aurocyanide, which may react with sodium sulphide according to the below equation:



The only gold ore containing carbon which I have had an opportunity of investigating carefully showed but little tendency to cause premature precipitation. This fact, together with its general appearance, led to the conclusion that the carbon in this ore was largely graphite. However, the graphite was found to definitely interfere with cyanidation. Experiments with deflocculation of the colloidal portion of the ore including the graphite gave negative results, but it was discovered that if the physical state of the graphite were altered, most conveniently by heating, that the extraction was wonderfully improved. The results in Table I show clearly the effect of heating.

TABLE I

	Per Cent of Gold Extracted	Pounds of Cyanide Consumed	Per Cent Graphite
Wet slime	36.14	0.9	1.65
Dried at 100 deg. C.	64.60	0.6	...
Check	64.60	0.6	...
Heated to 300 deg. C.	80	0.7	1.55
Check	83.00	0.5	...
Wet slime boiled with water, graphite skimmed off.	58.00	0.6	...
Wet slime boiled with water, graphite not skimmed off.	54.60	1.32	...
Roasted in open dish.	90.10	0.12	0.63
Roasted in open dish.	90.10	0.24	0.63

Practically all gold or silver ores can be treated by the cyanide process or by the cyanide process in combination with some other preliminary or accessory treatment, with the exception perhaps of certain ores containing a considerable amount of copper, lead, etc. In such cases, the desirability of recovering the base metals leads to smelting the ore upon either the lead or copper basis, and the necessity for hydrometallurgical treatment for the recovery of the gold and silver disappears since the precious metals are recovered by the smelting operation in connection with the base metals. Despite the fact that most ores can be successfully treated by the skillful application of the cyanide process, either alone or in combination with other accessory operations, it cannot be said that such treatment is

*The writer has long used a system of alkalinity numbers, similar to the system proposed by Sherwood, except that instead of using a $n/5$ solution of acid, an empirical solution (in the case of oxalic acid 11.6071 grams per liter) is used. When a 50 c.c. sample of solution is taken for titration, each 0.1 c.c. of the acid required corresponds to 1 point of alkalinity; 100 points correspond to a saturated solution of lime in water at ordinary temperatures.

²² Precipitating Action of Carbon in Cyanide Solutions. W. R. Feldtmann. Trans. Inst. Min. and Met., London, April, 1915.

always profitable, so that much remains to be done in the way of simplifying and lowering the operating costs of hydrometallurgical processes for the treatment of gold and silver ores, and in many cases improving the percentage of extraction.

Exemplification of Present-Day Adaptation of the Cyanide Process.—A clearer understanding of the possibilities in connection with the treatment of complex ores will perhaps be gained from a consideration of the solution of certain ore treatment problems which are exemplified by some of the adaptations of cyanidation in use at present for the treatment of a great variety of ores. On account of the high percentage of the precious metals recovered, the ores treated may not be looked upon as being complex ores. Certain of the cases which are now cited as an accomplished fact at one time could not be treated, or were treated by a single simple process and a very much lower extraction realized. The metallurgical practice at the older mines has been largely a matter of evolution. For example, the cyanide process has been added to plate amalgamation; it has displaced the chlorination process, and has been combined with concentration for the treatment of a great variety of gold and silver ores.

Example A.—The Homestake mine³⁴ (Lead, S. D., U. S. A.) produces a low-grade gold ore (\$3.59 per ton) in which a considerable proportion of the gold occurs in the metallic state, therefore recoverable by plate amalgamation. However, this ore did not yield a high extraction, according to present standards, by plate amalgamation, although the process was carried to the extreme limit of its possibility through the introduction of an unusually large plate area. This was on account of the occurrence of a portion of the gold intimately associated with pyrite and arseno-pyrite. The recovery by plate amalgamation, the original process, was first supplemented by concentration, then concentration was discontinued and the cyanide process was introduced for treating the whole of the pulp. This recovered a much higher total percentage of the gold and permitted the shipment of the whole product as bullion. The pulp is separated into sand and slime—the sand treated by leaching in vats and the slime by leaching in the Merrill filter press. Table II gives the extraction results.*

TABLE II. HOMESTAKE MINE

	Per Cent
Extraction by amalgamation employing a large plate area.....	69.0
By amalgamation upon regrinding.....	0.8
By cyanidation from sand.....	15.1
By cyanidation from slime.....	9.7
Total by amalgamation and cyanidation (in 1914).....	94.6

Example B.—The Treadwell mine³⁵ and ³⁶ (Douglas Island, Alaska) produces a lower grade gold ore (\$2.85 per ton in 1914) than the Homestake. It is possible to make a considerable recovery of the gold by plate amalgamation. A portion of the gold in this ore occurs intimately associated with pyrite, therefore concentration has from the beginning followed plate amalgamation. The early practice was to roast the concentrate

and treat it locally by the Plattner chlorination process; later it was found more economical to ship the concentrate to Pacific Coast smelters. At the present time the concentrate is reground and cyanided locally so that this company ships its whole product as bullion. Unlike the Homestake, the balance of the tailing does not pay to cyanide. Table III gives the extraction results.

TABLE III. TREADWELL MINE

	Per Cent
Extraction by amalgamation employing a moderate plate area.....	48.6
By concentration.....	43.6
Total extraction by amalgamation and cyanidation.....	92.2
By cyanidation from the concentrate.....	97.2
Total net extraction by amalgamation, concentration and cyanidation of the concentrate.....	91.0

Example C.—The Cripple Creek ores³⁷ (Cripple Creek, Col.), of moderate grade (+1.00 oz. gold per ton), in which very finely divided native gold and the telluride minerals of gold, and to a slight extent those of silver, occur intimately associated with pyrite and other sulphide minerals, were formerly treated by roasting and barrel chlorination followed by concentration. The present practice is to roast, regrid in cyanide solution, concentrate on woolen blankets, separate into sand and slime, cyanide the sand by leaching and treat the slime either directly by pressure filters or by agitation and vacuum filtration. The blanket concentrate is either melted directly or is treated by amalgamation.

The general principle of blanket concentration is one of the most ancient of gold recovery processes, and therefore an operation which the modern metallurgist is prone to condemn when he first sees it in operation in a modern mill. However, careful investigation increases his respect for this time-honored method of gold recovery when he finds that under the special conditions obtaining in these plants it is performing a most useful function in a most economical manner. Table IV gives the extraction results.

TABLE IV. CRIPPLE CREEK

	Per Cent
Extraction by blanket concentration (approx.).....	25.0
By cyanidation (approx.).....	70 to 73.0
Total extraction by concentration and cyanidation (approx.).....	95 to 98.0

Example D.—The Portland Gold Mining Company's low-grade Cripple Creek ores,³⁸ generally below 0.15 oz. gold per ton (Cripple Creek, Col.), are of the same general character as the higher grade ore. The ore is crushed in cyanide solution, concentrated, and the sand separated from the slime. The sand is rejected, as it is too low-grade for further treatment, but the slime is cyanided. The concentrate is shipped a short distance to the smelter. Although more profitable under present conditions to ship the concentrate, it could be roasted and cyanided locally, or might possibly be treated by very fine grinding and direct cyanidation. Table V gives extraction results.

TABLE V. PORTLAND GOLD MINING COMPANY

	Per Cent
Extraction by concentration.....	28.0
By cyanidation from slime.....	52.0
Total extraction.....	80.0

Example E.—Goldfield Consolidated mine³⁹ and ⁴⁰ (Goldfield, Nevada) formerly produced a high-grade complex gold ore (average November, 1909, to Oct. 31, 1910, —1.785 oz. per ton), but as operations have continued

*The figures given for extraction in the different examples are not in all cases the same as those which have appeared in descriptions of the practice which have previously appeared. This comes about either through the realization of a better extraction on account of improvements in the practice or a decreased extraction through increased complexity of the ore. The brief resums of practice and figures for extraction given are strictly up to date and authoritative with but one exception. In this connection the writer is indebted to the following well known managers for supplying the necessary information and giving permission for its publication: Mr. Fred Bradley, Mr. Allan J. Clark, Mr. G. M. Taylor, Mr. Theobald H. Croese, Mr. A. H. Jones, Mr. R. B. Watson, Mr. J. W. Hutchinson, and others.

³⁴The Metallurgy of the Homestake Ore, by Allan J. Clark and W. J. Sharwood. Institution of Mining and Metallurgy. Vol. 22, pp. 63-176. Discussion, pp. 176-234.

³⁵The Treadwell Group of Mines, Douglas Island, Alaska, by Robert A. Kinzie. Trans. Amer. Inst. Min. Engrs. Vol. 34, pp. 334, 386.

³⁶The Cyanide Plant at the Treadwell Mines, Alaska, by W. P. Lass. Trans. Amer. Inst. Min. Engrs. Vol. 42, pp. 755-818.

³⁷Private notes of the author.

³⁸Private notes of the author.

³⁹Operation of the Goldfield Consolidated Mill, by J. W. Hutchinson. *Mining and Scientific Press*, Vol. 102, pp. 616-620, 652-654, 686-688, 716-719, 752-754.

⁴⁰Treatment of Concentrate at Goldfield Consolidated Mill, by J. W. Hutchinson. *Mining and Scientific Press*, Vol. 106, pp. 170-172, 204-209.

the grade has become lower. The old practice was to crush in water, amalgamate, concentrate and cyanide. The concentrate was treated by a special process and the residue shipped to the smelter. In the present practice amalgamation has been dispensed with and the concentrate is treated locally by cyanidation after roasting. Table VI summarizes the results.

TABLE VI. GOLDFIELD CONSOLIDATED

Old practice: (Average of ore Nov., 1909, to Oct., 1910—1.785 oz. gold per ton.)	
	Per Cent
Extraction by amalgamation.....	15.38
By concentration.....	56.86
By cyanidation.....	22.03
Total extraction.....	94.27
By cyanidation from the concentrate.....	95.44
Total net extraction by amalgamation, concentration, cyanidation and cyanidation of the concentrate.....	91.68
Recent practice: (Average of ore Jan., 1915, to Oct., 1915—0.533 oz. gold per ton.)	
	Per Cent
Extraction by concentration.....	32.28
By cyanidation.....	58.81
Total extraction.....	90.59
By cyanidation from concentrate.....	96.18
Total net extraction by concentration, cyanidation and cyanidation of concentrate.....	89.36

Example F.—The Belmont mine⁴¹ (Tonopah, Nev.) produces a siliceous silver-gold ore containing the sulphide, sulpho-antimonide and the selenide silver minerals. The ore is crushed in cyanide solution and concentrated prior to cyanide treatment by agitation and filtration. Average assay of ore for a thirty-day period in 1915: Gold, 0.32 oz.; silver, 32.1 oz per ton. Table VII gives extraction results.

TABLE VII. BELMONT MINE

	Silver, Per Cent	Gold, Per Cent
Percentage of extraction by concentration.....	9.0	6.0
By cyanidation.....	84.0	90.2
Total.....	93.0	96.2

Example G.—The San Rafael mine⁴² (Pachua, Mexico) produces a siliceous silver-gold ore containing the sulphide and sulpho-antimonide minerals of silver, silver sulphide predominating. The ore is crushed in cyanide solution and concentrated prior to cyanide treatment by agitation and filtration. Average assay of ore over a considerable period of time: Gold, 0.13 oz.; silver, 28.42 oz. per ton. Table VIII gives extraction results.

TABLE VIII. SAN RAFAEL MINE

	Silver Per Cent	Gold
Percentage of extraction by concentration.....	24.19	(not reported)
By cyanidation.....	67.24	(not reported)
Total extraction.....	91.43	97.08

Example H.—The Nipissing mine⁴³ and ⁴⁴ (Cobalt, Ont., Canada) produces a low-grade complex siliceous silver ore containing sulphide, antimonide and sulpho-antimonide minerals of silver together with many other impurities, as arsenic tellurium, cobalt, nickel, etc. The ore is crushed in a caustic soda solution followed by extremely fine grinding in the tube mill and reduction with aluminium. After filtration it is cyanided by agitation and filtration. During the early operation of the

mill the ore averaged 26.0 oz. silver per ton, but more recently it is of lower grade.

Percentage of extraction by cyanidation.....92.0 per cent

Example I.—The Nipissing mine⁴⁵ (Cobalt, Ont., Canada) also produces a very high-grade complex silver ore containing upwards of 10 per cent of silver, which occurs chiefly metallic and as dyscrasite with a variable proportion of the sulphide and sulpho-antimonide minerals of silver. The gangue is largely the arsenical minerals of cobalt and nickel containing tellurium, antimony, mercury and metallic bismuth. The ore is ground in a silex-lined tube mill with very strong cyanide solution and a large proportion of mercury. This is followed by cyanide treatment comprising agitation and filtration of the pulp.

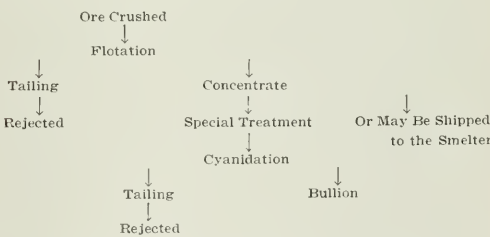
	Per Cent
Percentage of extraction by amalgamation.....	98.0
Percentage of extraction by cyanidation.....	1.0
Total.....	99.0

1. If the ordinary uncorrected assays are used, the bullion recovery frequently approximates 100 per cent.

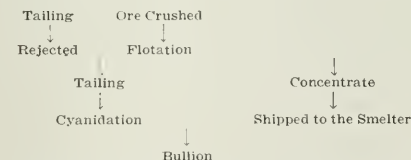
Example J.—The Alaska Gastineau Mining Company⁴⁶ (Juneau, Alaska) produces a very low-grade gold ore (\$1.25 per ton), having a slate, gabbro and quartz gangue in which occurs free gold, pyrite, pyrrhotite, galena and a little sphalerite. The ore is crushed and concentrated in water by ordinary gravity methods and the concentrate shipped to the smelter. Percentage of the gold extracted 84.0 per cent. This is a good exemplification of the application of the large scale methods which have been so successful in connection with the treatment of the low-grade porphyry copper ores to a gold ore which would be too low grade to be treated by any other method.

The following proposals for certain special cures of ore treatment are intended to be merely suggestive, as they are by no means fully proven nor do they entirely cover the range of possibilities. It is further realized that much investigative work is necessary to properly apply flotation in all cases to the treatment of gold and silver ores.

Proposal 1.—Very low-grade gold or silver ore which, owing to its complex nature and lowgrade, cannot be profitably treated directly by cyanidation:



Proposal 2.—Gold or silver ore containing sulphide, copper or zinc minerals which would interfere with cyanidation:



⁴¹The Tonopah Plant of the Belmont Milling Co., by A. H. Jones, August, 1915, *Bulletin American Institute of Mining Engineers*, pp. 1731-1758.

⁴²The Cyanide Mill of the S. Rafael y Anexas Co., Pachua, by E. Girault, *Transactions of the Mexican Institute of Mining and Metallurgy*, Vol. I, pp. 119-128.

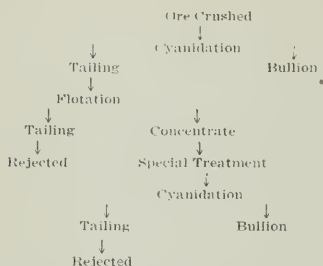
⁴³The Mill and Metallurgical Practice of the Nipissing Mining Co., Ltd., Cobalt, Ont., Canada, by James Johnson, *Transactions American Institute Mining Engineers*, Vol. 48, pp. 3-29. Discussion, pp. 30-32.

⁴⁴The Mill and Metallurgical Practice of the Nipissing Mining Co., Ltd., Cobalt, Ont., Canada, by G. H. Clevenger, *Transactions American Institute Mining Engineers*, Vol. 49, pp. 156-179. Discussion, pp. 179-182.

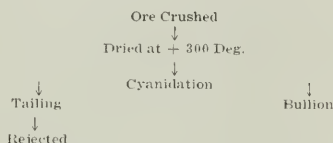
⁴⁵Nipissing High Grade Mill, Cobalt, by R. B. Watson, *Engineering and Mining Journal*, Vol. 94, pp. 1077-1080.

⁴⁶Perseverance Mine and Alaska Gastineau Mill, Robert S. Lewis, *Mining and Scientific Press*, Vol. III, pp. 337, 400.

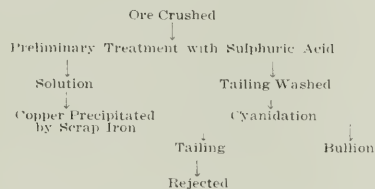
Proposal 3.—Typical gold or silver ore amenable to cyanidation where flotation might be applied to the tailing for the purpose of augmenting extraction:



Proposal 4.—Gold ore of moderate grade containing graphite which interferes with extraction:



Proposal 5.—Gold or silver ore in quartz or other gangue not acted upon by acid, containing oxidized copper minerals in sufficient amount to interfere with cyanidation:



Chemical Exhibition at Urbana Meeting of the American Chemical Society

The chemistry department of the University of Illinois is arranging an exhibition of chemical industries to be held in conjunction with the spring meeting of the American Chemical Society and the dedication of the new chemistry building at the University of Illinois, Urbana, Ill., April 17-21, 1916.

It is the purpose of the committee to emphasize especially the importance of American chemicals and apparatus, and at this critical time to make them better known. A large attendance of chemists is expected at the meeting, in addition to the 2000 students registered for courses in chemistry at the University of Illinois.

No charge is made to exhibitors for floor space; a nominal charge to cover the cost of printing a catalog will be made. Necessary gas, water, electricity and drayage will be furnished free. No admission fee is to be collected at the door.

Prof. H. L. Olin, Chemistry Building, University of Illinois, Urbana, Ill., is the chairman of the exhibits committee.

The Anaconda Copper Co. was forced to close its mines on Jan. 29, owing to the intense cold. The ore was frozen in the bins and cars and it was impossible to transport it to the smelters. After a few days' delay operations were resumed.

The Operation of the Blast Furnace The Sequences of the Charges which Occur

BY J. E. JOHNSON, JR.

The three articles on the principles of the blast furnace, published in recent issues of this journal, have necessarily to some extent formed a picture of the operation, but we may now consider in more detail the progressive changes which take place within the stack, first, in the raw materials as they descend, and second, in the gas as it ascends.

The Progress of the Raw Materials

While the changes through which these pass shade from one into another so that the number of stages is literally infinite, yet these stages may be divided into four main zones, first, that of drying and warming; second, that of the reduction of the ore, the decarbonating of the stone, and some solution of coke; third, incipient fusion, and the early stages of slag formation; fourth, the reduction of the last remaining portions of the ore from the slag, the completion of the carbonization of the iron, its siliconization, and also its impregnation with the phosphorus and manganese to the extent these may be present.

THE WARMING AND DRYING ZONE

As to the warming and drying zone not very much need be said. In coke furnaces in good practice there is a sufficient amount of residual heat in the gases at their exit from the stock column to give them a temperature of seldom less than 300 or 400 deg., and ranging from this up to a thousand, as we have seen in the article on thermal principles. This provides an ample interval between their temperature and that of the incoming raw materials to provide for the rapid drying and warming of the latter so that the temperature of the charge rises quite rapidly for a short distance below the stock line, and thereafter much more slowly because the temperature interval is much reduced by this rapid warming of the cold incoming stock.

THE ZONE OF REDUCTION

In passing through the second zone, the ore and fuel react with the ascending gases according to the complex laws set forth in the article on chemical principles. In a broad way oxygen is continually taken from the ore and imparted to the gas so that the content of oxygen in the latter constantly rises in its progress through this zone, but in detail we have the complicated reactions whereby the CO of the gas is broken by the catalytic action of the iron ore into CO₂ and C, the latter being deposited as an impalpable dust in the interstices of the charge, thus obstructing the free passage of the gas through it and not infrequently raising the resistance in this zone and the pressure below it. This carbon dust is carried down with the charge to a zone of higher temperature in which the ore can no longer remain in equilibrium with the carbon, so that the latter takes part of the remaining oxygen from the ore, is reconverted into CO, and rises again with the rest of the gas, perhaps to go through the same reaction again.

In this zone also the carbon dioxide of the limestone is driven off by heat, the greater portion of this action probably taking place in the upper portion of the zone. This, of course, results in adding to the gas additional CO₂ which entirely alters the equilibrium relation between the gas as a whole and the ore and carbon of the charge, a portion of the latter being absorbed by the gas to reduce a part of this CO₂ to CO and restore the equilibrium.

Frank C. Roberts several years ago called attention to a case in which a furnace which had been using a coarse, lumpy limestone changed to a rather finely crushed stone, with the result that slips became much more pronounced. The operators finally decided that the change in the size of the limestone was the cause of the slips and upon going back to the larger stone these were accordingly reduced to what they had been before the change was made. Mr. Roberts accounted for this on the hypothesis that with the lumpy stone, because of the time required for the heat to penetrate the large lumps, decarbonization was delayed down to the point where carbon deposition was taking place freely. The result was that the CO_2 from the stone dissolved the carbon dust deposited and prevented it from obstructing the interstices in that zone, leaving a free passage for the gas. With the smaller stone, on the other hand, the CO_2 was driven off at a level above that at which the carbon deposition took place, and the latter was, therefore, not removed by this agency, with the result that a tight zone was formed with slipping as a direct consequence.

I have no experience of the conditions described myself, but the explanation, in addition to being very ingenious, is entirely reasonable and illustrates how difficult it is to determine in advance the effect of any given change on the operation of a furnace, for it is almost universally believed and is probably very generally true that limestone crushed down to a reasonable size is very much to be preferred to coarse, lumpy stone.

Where the ores charged are in the form of lumps, or particularly if the ore be magnetite, the action of reduction is very much slower and the individual pieces of ore may descend well down toward the top of the bosh before they are disintegrated by the reducing action. If the ores are both magnetic and lumpy both causes contribute toward a still further delay in reduction, and we are likely to have solid lumps of ore descending into the bosh and even into the hearth of the furnace, where it is certain that they are reduced by the direct action of carbon with all the loss of both heat and fuel which have been shown to inhere in that action. Such furnaces must inevitably suffer from a fuel consumption materially higher than that of a furnace working on ores inherently more reducible or better prepared. On the other hand, we have come within recent years to realize that ores may cause almost as great fuel loss by being too reducible as by being too irreducible.

With the introduction of large percentages of Mesabi into the burden, the universal experience was that the furnaces worked very much more irregularly with more frequent and much more violent slipping and kicking, with not infrequent explosions of a much more violent nature which we will consider later, and that the fuel consumption was materially increased, even on furnaces working, for the time being, free from slips; so that the increased fuel could not be charged to the irregularity of the descent of the material into the hearth.

The reason for this increase in fuel does not seem to have been understood by anyone until within a year or two. In the summer of 1913 I obtained some authentic data as to the quantity of blast required to burn a pound of coke based on a vast amount of accurate and reliable investigation at one of the largest plants in the country. This amount was 51.4 cu. ft., whereas the amount required to burn a pound of the same coke, if there were no solution loss, under the same circumstances, would have been about 63

cu. ft. Obviously, then, the solution loss under these conditions was about 20 per cent.

I had recently been making some investigations based on the practice described in the paper of Mr. Arnold K. Reese before mentioned, in which the solution loss based on both engine displacements and gas analysis seemed to have been very small, while the fuel consumption for this run which was made altogether on Old-Range ores was, if not a record, at least within a few pounds of any authentic record made until very recent months. What could cause this enormous difference in the solution loss? It may be remarked that making allowance for the solution loss in modern practice the amount of fuel per pound of iron actually burned in front of the tuyeres was almost identical in the two cases, perhaps about a hundred pounds higher in the modern practice, corresponding to a slight increase in the slag volume as compared with Reese's comparatively rich mixture, the difference accounted for by solution alone amounting to about 400 lb. per ton of iron.

The difference in the physical condition of the ore was the only notable difference in the two cases. In Reese's practice the ores were Old-Range, so either lumpy or plastic, and contained no fine sandy material, whereas in the case taken from modern practice the burden was some 80 per cent Mesabi. When a layer of lumpy or plastic ore is charged upon a layer of coke it has little opportunity even after thorough drying out to run down into the interstices of the coke; the lumps, of course, cannot so run and the plastic material when dried out becomes not powdery but lumpy and is, therefore, almost equally unable to penetrate through the coke charge.

With fine, sandy ores the conditions are totally different. As soon as the ore becomes thoroughly dried a large portion of it runs almost like a liquid, especially when in a state of constant agitation caused by the gas current passing up through it, and this portion of the ore rests not only upon the top surface of the coke charge, but runs all through it and makes contact with the coke practically throughout the mass of the coke charge. It must be remembered that ferric oxide and carbon in contact at any temperature above a few hundred degrees are essentially in unstable equilibrium, and that direct action takes place between them, a part of the oxygen of the ore attacking the carbon and carrying it off as CO.

With the Old-Range ores this action could only take place along a single plane of contact, but with the fine, sandy ore scattered throughout the mass the number of points of contact is almost infinitely increased, and obviously the solution loss must necessarily be very much higher under these circumstances than with lumpy or plastic ores.

This, then, taken with the effect of solution loss set forth in the article on thermal principles, forms the explanation of the greatly increased fuel consumption of furnaces working fine ores over those using ores of similar analysis but different physical characteristics.

There has been for many decades, and probably many centuries, a strong prejudice among furnacemen against the use of fine ores, and it is probable that this action just described is responsible for a great portion of this prejudice. Moreover, with certain kinds of fine ore the conditions may be even worse. Furnaces working on fine magnetic concentrates have had the greatest difficulty in securing regular work, irrespective of the care with which the furnace might be burdened and filled, for the reason that the fine ore, as the furnacemen expressively de-

scribe it, "runs ahead." That is to say, under the agitation of the gas current it runs almost like a liquid, not only down through one fuel charge but perhaps through several if the conditions happen to be just right, and owing to its irreducibility, and to its having reached the hearth perhaps several hours ahead of the fuel which should have accompanied it, the furnace is unable to carry the additional load and serious trouble results.

In recent years much progress has been made in treating fine ores before charging them so as to convert them into some form of lumps. This was originally undertaken with the purpose of preventing the very fine portions from being carried out by the top gases and lost, but it has been found that in some cases a real benefit to the operation of the furnace has been brought about, and the reason for this improvement is believed to be that set forth above, that the physical structure of the ore is so changed as to prevent its running through the charge. Perhaps in some cases also, the lumps act as a blanket on top of the coke to prevent fine portions of the ore charge from finding their way down into the coke. Several of these processes reduce the ore partly to the condition of magnetite and thereby decrease its reducibility, but leave the product so porous that the gas and heat have free access to its interior portions, and so prevent its acting as do the large irreducible lumps of magnetite above described.

Throughout this zone of preliminary reduction a continual warming up of the ore takes place, partly by the physical absorption of the heat of the ascending gas current, and partly by the action of the oxygen of the ore in oxidizing the CO formed in the hearth to CO_2 , a reaction which gives off more heat per unit of oxygen than is absorbed by the removal of the same amount from the ore and therefore produces a net increase in the amount of heat present.

It will be noted from the equilibrium diagram in the chapter on chemical principles that the equilibrium line for both Fe_2O_3 and FeO descends toward the right or high-temperature side of the diagram, which means that as the quantity of oxygen remaining in the ore is reduced a higher heat and higher percentage of CO in the gas is required to remove the remaining portions, and as the ore descends these are precisely the conditions into which it passes, a continually increasing temperature, and increasing concentration of CO in the gas until at the top of the bosh practically all the carbon in the gas is in that condition.

It is probable that it is because of the long slow slope of these equilibrium lines that this second zone of the furnace requires to be the largest of any in point of size, almost as large as all the other three put together, so that time and space may be allowed for the relatively small but approximately constant reaction pressure (to coin a crude term), to do thoroughly and well its work of preparing the ore as completely as possible for the final operations which take place in the hearth and bosh.

Many other reactions and changes probably go on within this region but from the point of view of operation these are the only ones with which we need to concern ourselves.

THE ZONE OF PRELIMINARY SLAG FORMATION

This zone is one located approximately at the top of the bosh where, as we have previously seen, the materials pass through a pasty stage and finally into a fluid slag, but one by no means of the composition which subsequently is tapped from the furnace.

In a paper of Mr. F. E. Bachman before the American

Iron and Steel Institute in October, 1914, occurs the following paragraph which describes in a few words better than anything I have ever seen the action which I believe takes place in this zone.

"My conception of the formation of a blast furnace slag is that at a point approximately 25 feet above the tuyeres the minerals which have the lowest melting point in the ore begin to melt, then the free SiO_2 combines with FeO and with the melted minerals forms a fusible slag somewhat similar to heating furnace cinder. This slag flows down over the pieces of lime and coke, and when it reaches the hotter section of the furnace, the FeO is gradually reduced to Fe and replaced by CaO or by CaO and MgO from the lumps of burned stone. In front of and immediately above the tuyeres the coke ash is set free and combined with the slag produced above, and a portion of the lime not completely fluxed often passes below the tuyeres and is absorbed in the bath of slag in the hearth."

It may be doubted whether in practice other than that described by Mr. Bachman the initial fusion of the materials takes place as high as twenty-five feet above the tuyeres. It seems likely that in furnaces on Lake ores this height is more likely 15 to 20 ft., but leaving aside this detail the fact that slags form in a broad way as described by Mr. Bachman cannot be too strongly emphasized. The furnace does not make initially a clean iron-free slag of the final composition which we tap out, but following the law of most metallurgical operations it makes first of all a slag to suit itself, that is the most fusible one which can be produced from the ingredients present.

Oxide of iron lowers the melting point of lime-silica slags by several hundred degrees, and these are, as Mr. Bachman states, of the general nature of mill cinder, although probably considerably limier than that material. We never see anything of this intermediate slag when the furnace is in normal operation, but when it is in trouble and without sufficient heat in the hearth to furnish the reducing action we obtain from it to our sorrow slags of various and sundry descriptions, some of them thin, flowing almost like water at temperatures literally hundreds of degrees below the running temperature even of charcoal slags, and yet with so little reserve of heat above their melting point that the liquid surface can hardly be seen for the scull which freezes over it instantly when it strikes the air, and a hand-ladle dipped into such a slag for a sample will come out with a heavy crust instantly frozen on its surface, not tough or pasty, but sharp and brittle almost like ice, and as black as pitch itself.

These slags have compositions varying over a very wide range, but the most fusible one that I have ever seen contained a large percentage of iron, something like 35% FeO . In normal operation probably there is not in the zone of initial fusion sufficient unreduced iron to form a slag of this composition, but there is enough to form one of the stiffer and more plastic and more infusible slags such as we sometimes obtain from a furnace when it is limed up, that is, when the fusion point of the slag has been raised so high by excessive lime that there is not enough heat above its running temperature to give it complete fusibility or to remove all the iron from it, it is probably such a slag as this which first forms in the upper portion of the pasty zone. All the observations which we have of the slag from furnaces in normal operation, but taken from above the tuyeres, are of this general character, tough and black, proving the presence in them of some iron still unreduced. This, for instance, is the character of the slags which drip down from above when we are changing tuyeres and coolers or the like.

It is well to note how completely this physical evidence of unreduced iron in the hearth of the furnace agrees with the deduction in the article on thermal principles that the final reduction of the iron is not accomplished until it descends into the bosh. We have here a conclusion reached upon theoretical grounds, born out by all the objective evidence available.

In considering the matter of slag formation there are several points of much importance to be borne in mind. The first two are those mentioned in the article on chemical principles. First, that the formation temperature of slags is generally higher than their fusion temperature which is almost a corollary of the fact that the fusion temperature of the ingredients is far higher than that of the slags. Second, that the fineness of subdivision and intimacy of mixture of the different ingredients has a pronounced effect upon the formation temperature; as it is almost obvious that it should in view of the first condition.

In addition to these it must be noted that in coke practice a very large proportion of the total silica to be fluxed comes from the coke. In most Lake ore practice this probably amounts to about one-half, the other half coming from the gangue of the ore. Now no matter how intimately the flux and the ore may be mixed the lime must be in great excess at the top of the bosh because approximately one-half of the silica contained in the coke is locked up securely therein and is not all exposed to the solvent action of the slag until the coke has all been burned away which as we know does not take place until it reaches the tuyere zone. It is obvious, therefore, that we must have a much limier and therefore more infusible slag at the top of the bosh where the temperature is relatively low than we have in front of the tuyeres where the temperature is at its maximum. Considering the extremely stiff and pasty nature of these excessively limey slags, judging by the occasional ones which we get from the furnace, it is not a matter of surprise that the zone of incipient fusion should be a pasty zone, but rather that it is not a much pastier one, as in fact it probably would be were it not for the presence of the considerable percentages of iron oxide with its strong action in lowering the melting point.

With those classes of ores which contain an excess of lime such as the hard red ores of Alabama we have a somewhat different condition in respect to slag formation than that which exists with ores containing roughly the same amount of silica per unit of iron, but which require to be fluxed by the use of limestone additions. In the first case the lime and silica of the ore are in very intimate contact, and therefore the formation of the slag is greatly promoted, whereas when the silica is in intimate association with the iron alone and must be fluxed by separate lumps of lime derived from the limestone, the tendency is for the silica to unite with the iron in its partly reduced condition and carry it out of the furnace as a black slag, and either more time or more heat must be provided to obtain equally complete reduction in the latter case. This probably accounts for the fact that the soft red ores of Alabama, having virtually the same ratio of silica to iron as the hard ores, are much less desirable in the furnace. Either slower driving or more fuel is required in exact accordance with the above reasoning, for which I am indebted to Mr. W. L. Kluttz.

IMPREGNATION OF THE FUEL WITH SLAG

In connection with the necessity for reasonable fluidity on the part of the slag it may be as well to call attention here to a curious fact of practice which, if it has been observed, has at least not been the subject of any published comment of which I am aware.

Several years ago seeing a pile of carefully screened slag which had been lying in the weather for some time I noticed scattered through it several pieces of material which looked like coke except that instead of being black they were rust-colored, and when picked up were found to be very heavy, perhaps twice the weight of coke. The question as to what this material might be was discussed between the manager of the plant and myself with much interest. Finally we broke open one of the lumps and found that it was coke impregnated with some other material. Mr. B. G. Klugh was chemist of the plant at the time and on being called in he ground up and polished a broken face of one of these specimens; examination immediately showed that a great percentage of the cell spaces, even in the very center of the original lumps, was impregnated with slag. Subsequent investigation at other plants showed that all the coke which came from the tapping hole and had therefore passed through the hearth, was in this condition. In some cases particles of iron as well as slag were found in the center of the pieces of coke. It was noticeable that this slag was always milk-white, irrespective of the slag which the furnace might be making at the time.

When I first began to operate a charcoal furnace I noticed on the casting cinder little piles of coarse fibers about like white horsehair, the individual fibers two or three inches long, and not lying crisscross but parallel as if they had come done up in a neat package. I asked what caused this but obtained no satisfaction. A short time after, however, coming past soon after cast, when the cinder was still hot, I noticed pieces of charcoal with a white appearance around their ends in various stages of very slow combustion, no flame, merely a quiet dull red glow hardly visible, by which the carbon was slowly passing away. Closer examination showed that the white appearance at the ends was due to the projection of fibers projecting from the cells, and presently it became evident that the neat little packages of "horsehair" were fibers of slag cast absolutely perfect into the cells of the coal in the hearth, and exposed by the slow burning away of the charcoal as it lay on the hot slag in the open air. Analysis of this material proved it to have the same composition as the main body of the slag made at the same time.

The extreme whiteness of the slag in both these cases is an index of the completeness with which the iron oxide is reduced and removed from it, and suggests the possibility that this extraordinarily intimate contact between the slag and the fuel may be a factor of some practical importance in the final completion of the smelting operation, and certainly it is a factor which can not exist except with a reasonably fluid condition of the slag.

THE ZONE OF FINAL OPERATIONS

This is the region of highest temperature in the furnace extending from a short distance above, to just below, the tuyeres. In it the slag attains its final composition, the coke having all burned away and released the slag-forming ingredients which it contains, while the intense heat suffices, in a proper-working furnace, to deoxidize the last remaining portions of the iron and causes them to enter the iron bath leaving a slag which in good practice contains only two or three tenths of 1 per cent of iron.

In coke practice, owing to the fact that the slags used are on the lime side of the most fusible ratio of lime to silica, additions of silica cause the production of a more fusible slag, hence the release of the silica from the coke ash, and the increase in temperature, owing to the conditions in the region, both contribute to make the slag more fluid. As we have many times re-

iterated, the critical temperature of the furnace not only in the theoretical sense of that word but in the actual sense that the operation of the furnace depends upon it, is that temperature at which the slag becomes sufficiently fluid to free the remaining traces of iron, both shot and oxide, which it contains, and sufficiently mobile to cover the coke and carry away practically all the sulphur it contains, as fast as the latter is disengaged, thus keeping all but small traces out of the iron.

We see, therefore, that the slag has only to reach this condition in its final stage, but it is absolutely essential that it be reached, if not, evil consequences will follow very rapidly. First, the sulphur is no longer sufficiently absorbed by the slag, and deleterious quantities enter the iron lowering its value and finally reducing it to a non-merchantable commodity. Simultaneously with this begin considerable losses of iron carried off with the slag, sometimes as shot, more often in the form of ferrous oxide dissolved in it, and finally as an inextricable mixture of bad iron and bad slag which do not separate instantly with a clean line of parting like oil and water, but which, partly for physical and partly for chemical reasons, remain mixed together if not dissolved one in the other.

Following these conditions, the slag becomes too stiff to be flushed from the furnace through the ordinary opening of one to two inches in diameter, and the water-cooled monkey through which this operation is performed must be removed bodily making a hole some 6 to 10 in. in diameter through which the slag will flow unless the furnace is lime-set or in serious trouble from lack of heat. "Lime-set" was a term used principally by the furnacemen of an older generation, before the simple principles of furnace burdening were as well understood as they are now, to describe the condition to which furnaces were not infrequently brought by the addition of more and more lime to accomplish certain results in the kind of iron produced, or through a misunderstanding of some abnormal condition of the furnace and attempting to correct it with what turned out to be an overdose of lime.

The fusion temperature of slags with increasing lime content goes up with great rapidity, and after a certain point is reached the free-running temperature of the slag becomes higher than any temperature obtainable within the hearth of the ordinary blast furnace, with the result that the slag cannot be removed, and if the furnace continues to be blown this infusible slag rapidly builds up in the hearth and bosh making it more and more difficult for the blast to penetrate from the tuyeres up through the stock column until finally the hearth and bosh of the furnace are almost filled solid with this excessively limey material, which when it is exposed to air or cooled off, not infrequently breaks down much like slacked lime.

In charcoal furnaces occasionally we reach a similar condition from a cause exactly the opposite since slags containing a great excess of silica while they are not as infusible as those containing a similar excess of lime, are extremely stringy and viscous, with the result that at the comparatively low temperatures of the charcoal furnace they may build up on its walls almost as badly as do excessively limey slags in the coke furnace. But the temperature range through which they may be made to flow, even if slowly, is wider than in the case of the limey slags, and charcoal furnaces are therefore not so liable to become completely "bunded up" in the expressive language of the furnace man, from this cause as were coke furnaces a few years ago.

In this zone important changes occur in the iron it-

self. We have already seen that the silicon and phosphorus can only be reduced in the presence of incandescent carbon at the highest temperatures obtainable in the furnace, and when the iron is present to absorb them. The same thing is true of the manganese in a less degree. That is to say, a furnace charged with an ore of phosphorus or silicon without iron would not reduce any of those materials, and a blast furnace operated in the ordinary way charged with manganese ore without iron would reduce little or none of that element, although by material changes from regular iron furnace practice it can be made to do so. In order then that these elements may be reduced, it is necessary that the iron be present as such so that its affinity for them may assist the action of the incandescent carbon and the high temperature in reducing them from their oxides.

These actions, therefore, go on exclusively in the hearth. It is probable that a large portion of the carbonization in the iron also goes on at this point because it is quite difficult, by any other process, to make iron absorb as much carbon as the product of the blast furnace ordinarily contains. Even the electric furnace with its enormous temperature has found some difficulty in securing the conditions which would give the carbonization of iron necessary to constitute real cast iron, while other methods of melting have generally not been able to raise the carbon much, if any, above 3 per cent.

In the hearth of the furnace we have the condition that iron is subdivided into extremely small streams, trickling down over incandescent coke, in an atmosphere as reducing as it is possible to produce, and at the highest temperature of the furnace. Under these conditions the completion of the carbon absorption takes place.

As to how much carbon is absorbed in the regions above this we do not know. We do know that iron exposed to intimate contact with fine carbon over long periods of time and fairly high temperatures, absorbs 1 or 2 per cent of carbon, and when the ore is of a nature to produce the deposition of carbon dust from the gas upon itself, we have the conditions under which carbonization may easily take place, but so far as I know no determinations have ever been made as to the extent of this action.

In addition to these, other actions go on in the hearth, and some of them we find it extremely difficult to account for. One of the most notable problems is the composition of the salamander taken from the hearth when the furnace is blown out. Salamander is a term covering literally a multitude of sins.

The salamander of the old-fashioned charcoal furnace consisted of what geologists would call "pudding stone," of charcoal slag of all colors and compositions, interlaced and tied together with a stringy or sponge-like mass of iron.

In coke furnaces we find masses not unlike this in general characteristics except that imbedded coke is rare, and the iron portion of the structure is less sponge-like. The intimate mixture in this case is of iron, slag, graphite, and sometimes firebrick, but in the center of the coke furnace we usually find a depression well below the level of the original brick hearth of the furnace filled with iron, which, below the surface, is quite unmixed with slag. The body of solid iron varies much in size and is generally very graphitic around the edges, but frequently extremely dense and solid in the center. Sometimes this mass consists only of the frozen pool of metal last formed in the furnace which could not be removed from it because of its depth and of the absence of a sufficient blast pressure to lift it out through the tapping

hole. But usually in addition to this there is another mass below it, and generally quite distinct from it, which likewise consists of solid iron, but whose composition bears apparently no relation whatever to the composition of the iron made during any portion of the blast. For instance, it is well known that the affinity of iron for phosphorus is so great that practically all the phosphorus introduced into the charge is taken into the iron, yet these salamanders often contain only a small fraction of the phosphorus contained by the iron made during the blast. The manganese is generally low, the silicon also is quite low, and the carbon which in cast iron runs practically always from $3\frac{1}{2}$ to $4\frac{1}{4}$ per cent; I have seen in one of these salamanders down to about 1.5 per cent.

This material was really a poor grade of high-carbon steel of which the crystals were distinctly bent when the broken faces were slid over one another, and of which a piece taken to the blacksmith's shop could almost, but not quite, be forged.

I am advised by John M. Reese that he has had a practically identical experience.

Comparing the analysis of such a material with the pig iron from which it has presumably been produced, we can only reach the conclusion that there has gone on here a slow but none the less effective oxidizing action at the bottom of the bath although cut off from access to the blast by a layer of iron or slag, or both, and at cast time when the hearth is relatively bare, covered by a mass of coke several feet in depth below the tuyeres, conditions apparently precluding any possibility of access to this region by the oxygen of the blast.

The cause of this peculiar action is not fully understood as far as known to me, but it is impossible to resist the conclusion that the oxidation must be carried on by slag not completely reduced; of the kind which we always find trickling down the walls whenever we have occasion to investigate conditions.

It would seem necessary to suppose that oxygen in this form is carried down into the hearth, that it is cut off from the reducing action of the coke column by the fact that the latter is in part floated on the surface of the charge as described in a previous article, and that this slag which is known to be a very active oxidizing agent satisfies its desire for oxygen at the expense of the metaloids in the plastic but not quite fluid mass of iron in the bottom of the furnace.

The mechanism by which this action is carried out I do not pretend to understand. If anyone will work it out and publish the results he will satisfy the acute scientific curiosity of a great number of his professional brethren by so doing.

The Asphalt Primer and Colloidal Catechism is a little pamphlet issued by the Barber Asphalt Paving Company of Philadelphia. It is an exceedingly clever piece of propaganda, interestingly written and catchingly illustrated. It starts with ancient road construction, going back to King Cheops and the Via Appia of the Romans, compares ancient and modern road construction, and deals with asphalt and its function in a paving mixture. The fact that Trinidad Lake asphalt contains colloidal matter is emphasized and simple explanations are given of such terms as colloids, surface energy, and adsorption; and what they have to do with paving mixtures. In a most skilful manner the non-suspecting lay reader is led to absorb some highly modern chemistry and the primer winds up with a tribute to colloidal chemistry for placing the formulation of paving mixtures on a scientific basis and for accounting for the established excellence of Trinidad lake asphalt.

Liquid Chlorine*

BY DR. G. ORNSTEIN

All are familiar with the element chlorine—its history, manufacture and characteristics—so that it will be hardly necessary to go into details on this subject.

CHEMICAL PROCESSES FOR PRODUCING CHLORINE

The first process employed commercially was the same which we have all used as students in the laboratory—namely, that of generating it from manganese and acid, which may be either muriatic or a mixture of salt and sulphuric acid.

This process was made eminently practical later on by Weldon's invention of recovering the manganese by means of addition of lime to the waste liquor, blowing air through the mixture, and returning it in this regenerated form to the process. This Weldon process is the only purely chemical process operated on a commercial scale, which has furnished a chlorine gas of sufficient concentration to be used for liquefaction. The Deacon process in which hydrochloric acid fumes are decomposed in the presence of air and a contact substance, such as copper chlorides, yields a weak gas which is not practicable for the purpose of liquefaction—at least not directly.

To overcome this drawback in this process and in other instances where a weak chlorine gas is obtained, several processes protected by patents have been worked out, particularly by Goldschmidt and Sperry, which aim at absorbing the chlorine from a weak mixture, the former by stannic chloride, the latter in the form of chlorine hydrate, thus separating it from the diluting impurities and later on decomposing it again by application of heat for the purpose of producing pure chlorine. In the Acker process, in which an extremely poor gas was obtained, one went even so far as to first convert the chlorine into bleaching powder and subsequently decompose it by acid.

However, it seems that none of the chemical processes are operated any longer for the purpose of liquefaction, except perhaps in a few individual instances, and the chlorine liquefied nowadays, in this country as well as abroad, is almost entirely produced by electrolytic processes.

ELECTROCHEMICAL PROCESSES FOR PRODUCING CHLORINE

The electrolytic decomposition of brine or muriate of potash is well known in principle. It consists in passing an electric current of high amperage through an electrolytic cell, in which the anode is made of carbon, or what is much to be preferred, Acheson graphite, or fused iron oxide, while the cathode consists of iron, either in the form of a perforated sheet or wire screen, or in some instances a solid sheet depending on the details of construction.

When the electric current is passed through the cell the brine is split up into its components; chlorine will escape at the anode and caustic soda or caustic potash will be produced at the cathode. The products of electrolysis have to be kept apart, as otherwise they will combine, forming hypochlorite and eventually chlorates, and quite a number of constructions have been devised and patented to prevent this re-combination. In the larger number of constructions diaphragms of various designs are employed—for instance, in the Gibbs, Townsend, McDonald, and Billiter cells the basis of the diaphragm being mostly asbestos. In others they are kept apart by gravity and by causing a constant flow

*A paper presented at the meeting of the American Electrochemical Society (N. Y. Sec.), on February 11, 1916 (in joint session with the New York Sections of the American Chemical Society and the Society of Chemical Industry).

of liquid in the direction from the anode to the cathode. This principle is employed, among others, in the "bell process."

A third principle is employed in the mercury cell, in which the cathode is formed by mercury instead of iron, absorbing the sodium or potassium under the influence of the electric current, and this in turn is released again by water outside of the electrolytic cell in the form of caustic. The pure mercury is then again returned to the cell and reloaded at the cathode—but no matter of what construction the cell may be, in all instances a highly concentrated chlorine can be obtained which, with graphite or iron oxide anodes being less subject to electrolytic oxidation than carbon, should easily yield gas of 97 to 98 per cent purity, the balance being carbon dioxide, electrolytic oxygen and a slight trace of air. With iron oxide electrodes, of course, no carbon dioxide can be formed, but the amount of electrolytic oxygen will be correspondingly higher. However, only in a few cells a gas of this purity is actually obtained, on account of mechanical defects, such as leaks in the cell covers or pipe lines, or negligence of the cell attendants.

LIQUEFYING CHLORINE GAS

For the liquefaction of chlorine it is of great importance that attention should be paid to generating a highly concentrated gas, because otherwise the percentage which can be liquefied from a certain volume of chlorine will decrease rapidly with each per cent of impurities.*

The balance, which still contains between 55 and 65 per cent of chlorine, is called blow-off gas and is released from the liquefying machinery, from time to time, when the pressure exceeds certain limits. It is generally conveyed to the bleach chambers; this is the preferred way of both using and getting rid of it, as on account of its dilution it can be used only for a limited number of other purposes.

In any case absorption capacity of some kind has to be provided for, and it therefore appears that a chlorine liquefaction plant can be operated to advantage only in connection with the manufacture of other chlorine products.

HISTORY OF LIQUID CHLORINE

A great many attempts have been made to liquefy chlorine ever since the beginning of the nineteenth century, but until recently they were largely confined to laboratory experiments without any practical value.

The first liquid chlorine was obtained in 1805 by Northmore, and as early as 1823 Faraday demonstrated the well-known experiment which is found in every text book, namely, the decomposition of chlorine hydrate in a sealed and bent glass tube, the hydrate being heated in one branch of the tube and the escaping chlorine being liquefied in the other branch, which is cooled in a freezing mixture. But until after 1880 nothing had been done which could justify any hope of success for working out a commercial process.

Between 1880 and 1890 a number of processes were worked out which at least made an attempt to produce liquid chlorine on a commercial scale. For instance, Vautin attempted to compress chlorine gas by pressing air into tanks containing chlorine and at the same time cooling it down to a low temperature.

Others, for instance Hannay and Marx, based their processes on the decomposition of chlorine hydrate in a closed vessel. Heinzerling attempted to reach his object by first compressing chlorine, cooling it to a low temperature and then liquefying it by sudden expansion.

But none of these attempts were successful and commercial liquid chlorine remained an unrealized dream until the arrival of the process of Knietsch, of the Badische Company, who in 1888 placed the first liquid chlorine on the market. He was the first to realize that it was of fundamental importance for the commercial liquefaction of chlorine that chlorine be used which is at once highly concentrated and free from moisture—two points which the former inventors had overlooked. He also found that chlorine carefully dried did neither attack iron nor a number of other metals employed for building commercial machinery, and through an ingenious device of a so-called liquid piston he was able to put the chlorine under a high pressure without any danger of leaking through the stuffing box around the piston, causing corrosion, etc., For the liquid media he used a column of petroleum around the piston, and below this and in the other branch of the U-shaped cylinder he used concentrated sulphuric acid. The liquid piston was lifted up and down by a plunger moving in the petroleum and thus sucked in and compressed chlorine gas which through a separator was carried on to a condenser where, under the influence of low temperature, it liquefied and was then filled in to the shipping containers.

He also heated the sulphuric acid by a steam or hot-water jacket in order to reduce the absorptive power of the acid for chlorine gas.

According to my knowledge most processes which are now in operation are still based on these fundamental principles. That is, all of them are using a liquid for compression, and while they may have been simplified in some way, for instance by omitting the petroleum and not heating the sulphuric acid or by making changes in other directions, compressing the chlorine by entrainment, or in two or three-stage compression, yet in almost every case the principle has been maintained.

There are several processes on the market, for instance that of the Linde Company of Germany, by which liquefaction is effected simply by cooling to -45°C . or below, without any pressure. But the drawback of this process is that the percentage liquefied is lower throughout than that obtained with the combined system of compressing and cooling.

Regarding the relative merits of the various processes I must hesitate to express an opinion. There is so much secrecy observed in this field, as in all lines of chemical industry, that I do not know enough about the details of construction and operation of most of the other manufacturers to warrant my passing comparative criticism on this subject.

In one point I feel "the people who know" will agree with me—stick to what you have got and have tried out in the course of years and of which you have studied all the little knacks and moods and—never mind what excellent results the other fellow "says" he gets. I would rather hunt for trouble in a twelve-cylinder automobile motor than tackle a chlorine compressor when it is in the mood of the "morning after the night before."

The liquid chlorine is shipped in steel cylinders containing about 100 lb. net and of a tare weight of 70 to 100 lb. In large quantities it is also shipped in tank cars. The pressure in these containers varies with the temperature from about 70 to 100 lb. per square inch at ordinary temperatures. But the pressure will drop rapidly on account of the heat consumed by evaporation if chlorine is drawn off continuously even in relatively small quantities.

In one place where chlorine was drawn off continuously for the purpose of water sterilization at a room

*The author showed curves illustrating the influence of concentrations as well as of pressure and temperature.

temperature of about 2 deg. C. the pressure dropped in 24 hours from around 55 to 15 lb., although not more than $\frac{3}{4}$ lb. per hour were taken from a set of four cylinders, or 3 oz. per hour per cylinder. This cooling or freezing action can be easily counteracted by playing steam on the cylinder until the frost which will form has disappeared, or by placing it in a tub with warm water or in a cabinet which is kept warm by artificial heat or similar means.

LIQUID CHLORINE IN THE UNITED STATES

In this country commercial liquid chlorine was unknown until the year 1909. There had been imported prior to this date quantities of liquid chlorine from Germany, but these were used solely for experimental purposes on a more or less extensive scale, but the United States did not begin any manufacture until 1909.

It was in the beginning of this year that the Electro Bleaching Gas Company, after about two years of experimenting, erected the first compressors, and a short while later two more chlorine concerns started in operation, the Goldschmidt Detinning Company and the Castner Electrolytic Alkali Company. The former one used the product largely for its own purposes, namely, the detinning of tin scrap, whereas we had to find and build up a market for this entirely new product.

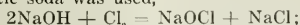
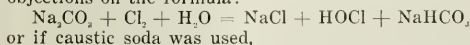
The two most important fields to which the liquid chlorine was to be introduced were the bleaching of vegetable fiber, such as cotton, flax and paper pulp, and chlorination of all kinds, such as ores, organic compounds, pharmaceutical products, etc.

Above all, we found it necessary to instruct our purchasers how to use the liquid chlorine for their various purposes, and we still recall with considerable pleasure the many comical occurrences which happened at that time. In one textile mill our friends apparently thought the cylinder contained something like a liquid bleaching powder which they had been accustomed to use for generations. So they simply attached a hose to the valve outlet and tried to empty the cylinder into a vat containing water for diluting to proper strength and then they opened the valve. The result may be easily imagined. After a minute or two there was nobody left in the mill who could be induced to enter the place and shut off the valve. The letter we received was all but complimentary. Many other episodes of a similar nature occurred.

Therefore, before we could market the product we had to instruct our purchasers how to use it, and we were compelled to make demonstrations of how to prepare the bleach liquor and how to bleach yarn with it in one mill after the other. Finally we succeeded in convincing a number of the largest and most conservative mills of the decided advantages of liquid chlorine as compared with bleaching powder, and these mills for the past four or five years have definitely abandoned the bleaching powder in favor of the liquid chlorine.

BLEACHING SOLUTIONS MADE FROM LIQUID CHLORINE AND BLEACHING POWDER

At the beginning we had to convince many chemists that the amount of available chlorine present in a bleaching solution prepared with liquid chlorine and alkali, for instance soda ash, was equal to the full amount of chlorine passed in. They were basing their objections on the formula:

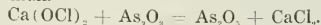


they insisted that these equations proved that one-half of the chlorine was converted into NaCl and thus wasted for bleaching purposes.

The assumption was that in bleaching powder the available chlorine was present in the form of a CaOCl_2 . As a matter of fact this is the most accepted formula for the powder, so that the impression is given as if all the chlorine present were in the available form; but upon dissolving this will be split up according to the equation,



so that one-half of the chlorine is converted into the chloride and the titration with As_2O_3 proceeds according to the formula



Thus it can be seen that the so-called available chlorine does not represent the actual amount of chlorine present in the hypochlorite, but only one-half of it, and is rather an expression for the available oxygen in the same compound which if expressed in chlorine value must, on account of the bivalency of the oxygen and the monovalency of the chlorine, naturally have twice the chlorine value.

It now follows from comparison of the above equations that the chemical reactions of bleaching powder solutions and solutions made with liquid chlorine and alkali are identical, and the fact can no longer be astonishing that if liquid chlorine is used for the manufacture of bleaching solution, an available chlorine content is obtained substantially equal to the number of pounds of chlorine absorbed by the solution.

We were able to show—and in connection with this wish to acknowledge the valuable assistance rendered us by Dr. J. M. Matthews—that bleach solutions thus prepared gave decidedly better results than bleaching powder. We could demonstrate that only one-half of the amount of available chlorine and even less is required to be present in order to give the full bleaching results which formerly had been obtained with chloride of lime, while the tensile strength of the goods is correspondingly improved.

A large reduction of the so-called sour, namely the use of weak sulphuric or muriatic acid after the bleaching bath for the purpose of destroying the last traces of residual chlorine, represented a further improvement in this important respect. The explanation for the increased efficiency seems to be that in case a bleach is used in which the chlorine has been combined with soda ash the presence of free hypochlorous acid causes a more rapid and more efficient action on the fiber than the neutral calcium hypochlorite. In addition any bleach prepared with soda as a basis and with entire absence of lime salts seems to have a higher penetrating power on the cloth on account of no substances being present which are capable of forming insoluble precipitates on the fiber. This theory is substantiated by the observation that a hard twisted yarn or cloth requires less available chlorine as compared with the necessary quantity of bleaching powder solution than a material of a looser texture.

OTHER ADVANTAGES OF LIQUID CHLORINE

Another large field in which liquid chlorine is now used extensively is for chemical chlorination processes, in which the quantities consumed are not large enough for warranting the concern to build a branch factory near the chlorine-producing concern for receiving the gas directly from the cells, so that the use of liquid chlorine, which is easily transportable, is the only other choice.

A number of manufacturers have tried to make the chlorine themselves from either bleaching powder and acid or manganese and acid, but in most instances they have found that it was much more to their advantage to purchase liquid chlorine ready made. The reason is

not only the cost of the raw materials, which in either case exceeds the price at which liquid chlorine can be purchased, but there is also the advantage of the liquid chlorine being absolutely dry, chemically pure, and under a pressure sufficiently high to be easily conveyed to any point of application and pressed through liquids to be treated without the troublesome medium of blowers, fans, pumps, etc.

The valve of the chlorine cylinder, also, permits of an easy and accurate regulation, whereas the above-mentioned chemical processes when once started cannot be regulated at will unless a gasometer is used in connection with them; this only introduces another source of trouble because as the only sealing medium concentrated sulphuric acid must be employed.

Of the advantages just cited, its purity is one of the most conspicuous characteristics of liquid chlorine. When a fresh cylinder is opened it will usually yield at once a gas which is 96 to 98 per cent pure, and after several pounds, from 3 to 5, have been taken out, it goes up to 99 per cent, and after another pound or two it will be at 99.7 and 99.98 per cent, and will stay there until the last drop of liquid has evaporated from the cylinder. In view of these figures, which can be easily substantiated at any time, liquid chlorine may justly be called one of the purest, if not *the* purest, chemical on the market. The initial slight amounts of impurities represent the small left-over traces of air, etc., which were in the gas coming from the cells.

LIQUID CHLORINE FOR WATER STERILIZATION

A third large field for the use of liquid chlorine has been opened up during the last three years, namely its use for the sterilization of city water supplies and sewage. In this field as well as in the bleaching industry liquid chlorine had to compete with its old competitor, bleaching powder, but we are proud to say that it has made a pretty good showing, even without making allowance for its youth and for the lack of experience.

After some experimental work had been done previously the first commercial machines were installed in the Western New York Water Company plant at Niagara Falls, N. Y., in November, 1912, where we received valuable assistance from F. H. Huy, general manager of the Western New York Water Company's plants, and in Wilmington, Del., in January, 1913, where they are still in continuous satisfactory operation. These machines are based on the principle of absorbing a measured quantity of chlorine in a small amount of water and subsequently adding this solution to the water to be treated. This so-called absorption process has the advantage of an even and rapid distribution of the sterilizing agent throughout the whole body of water. This advantage is particularly apparent in large installations, such as the Torresdale filter plant in Philadelphia, where from 220,000,000 to 330,000,000 gal. of water are filtered daily.

It is furthermore of advantage in plants in which the water to be treated is under high pressure—which in some places exceeds the pressure of the liquid chlorine itself. In these installations the application of the chlorine in the form of a solution which is forced into the main by means of a specially constructed pump is the only form in which the problem can be solved.

In the field of water sterilization the Leavitt-Jackson Engineering Company is deserving of particular mention on account of the original principle involved, which consists of feeding the chlorine into the water by weight by a balanced beam construction acting on the chlorine feed valve. This is an excellent construction mechanically, but not sensitive enough for the minute quantities

of chlorine which are required by far the largest number of water works.

The principle used in our first machine comprises the pressure regulation by a reducing valve or by two switched in series, the measuring of the rate of flow by the pressure difference on both sides of a calibrated orifice caused by it, and the subsequent absorption of this measured quantity in water prior to its addition to the main flow of water.

Under the conditions in which the chlorine in the absorption tower is discharged against atmospheric pressure it is unnecessary to connect the U-tube to the down-stream side of the orifice, as would have to be done were the chlorine to be discharged against pressures higher than atmospheric.

We are also using a rate of flow meter for measuring the chlorine.

Through constructions along these lines it has been possible to effect an accurate regulation of chlorine gas to any quantity as small as 1/40 oz. per hour and as high as 25 lb. per hour, irrespective of any variations of the pressure in the cylinder, which in the course of operation may drop from 100 to 15 lb. without influencing the rate of feed.

To realize thoroughly the importance of employing a sterilizing agent which can be added under perfect control as to its quantity, it is sufficient to point out that it is necessary to add it to a continuously flowing stream of water and that it has to be mixed and intermingled with it continuously, thoroughly and evenly. This is not possible with chloride of lime, because the devices used for this purpose, such as orifice boxes, etc., will after a short time be partly or entirely plugged up by a lime deposit and will be in full working order only for a few days at a time. We have also succeeded in developing apparatus capable of automatically varying the amount of chlorine added in proportion to the rate of water flow.

Further advantages which may be cited in favor of liquid chlorine are: absence of taste and odor in limits very much wider than those prevailing for bleaching powder—no sludge or dust—smell or other nuisance, and particularly its *efficiency*, which is two to three and one-half times as high as the same amount of available chlorine present in bleaching powder. In other words, 1 lb. of liquid chlorine has approximately the efficiency of 6 to 10 lb. of chloride of lime.

In these various directions we had first to overcome considerable prejudice on the side of the communities, particularly as regards taste and odor. To what extent prejudice may sometimes run away from common sense may best be learned from the fact that complaints about chlorine taste and odor came pouring into the office of the Board of Health in Buffalo—four weeks *before* our machines were installed.

The results obtained by this process and applied by these machines have been highly satisfactory, as can especially be gathered from the Board of Health records of the various communities which in cities which formerly had an exceedingly bad record for typhoid fever are now reported as being almost or entirely free from it, and in no case, wherever typhoid fever then occurred in such a community, has it been possible to trace it back to the water used, but the reasons were always found in causes other than the city water supplies, such as milk, impure food, etc.

LIQUID CHLORINE AND THE WAR

This evening's papers deal with electrochemical war supplies and I, therefore, have to devote some space to the use of liquid chlorine for war purposes.

The war has naturally had considerable influence on

the liquid chlorine trade, though the causes are entirely different from those which are responsible for the demoralization of prices of other chemicals.

For the latter the present situation is caused simply by the fact that they were hitherto imported from abroad and only small quantities, if any, manufactured here. Now the supplies being entirely shut off, prices, of course, have gone sky-high. Liquid chlorine, on the other hand, is a domestic material which, therefore, could not be influenced by the shutting off of imports as to the quantity available. The increase in the trade and the price of liquid chlorine must principally be traced back to the shortage of bleaching powder, of which formerly more than 50 per cent was imported, and on account of it being shut off its price has risen from about \$23 per ton to figures between \$200 and \$300, whereas the price of liquid chlorine has only increased from \$160 or \$200 per ton to \$240 or \$300. Taken in figures of available chlorine, which is the compound by which, apart from other considerations, the comparative values of the two materials are measured, this is now worth in bleach containing 35 per cent available chlorine \$570 to \$860 per ton, whereas in liquid chlorine, which can be almost quantitatively converted into the available form, it can be purchased for no more than the price of the liquid itself.

How long these conditions will continue to prevail is hard to say. Several of the big manufacturers are enlarging their plants and their bleach capacity, which may relieve the present shortage to some extent, but hardly enough to reduce prices to anywhere near normal. The enlargement of plants, however alluring, is carried out very conservatively, realizing that after re-establishment of peace the imports will begin again from Europe, particularly Germany and England, perhaps not immediately, as some assume, but soon after.

In the meantime the price of liquid chlorine may still travel a long way upward before approaching the present value of available chlorine in bleaching powder.

Due to this condition, namely, a price enormously higher for bleach than for liquid chlorine, manufacturers have been much tempted to divert part of the chlorine from the liquefying machinery into the bleach chambers, and a certain stringency may have been caused by this, as well as by the exportation of moderate quantities for war purposes.

From the reports we have received from the other side, liquid chlorine as such has been used as a weapon for incapacitating the enemy. To what extent these reports are strictly true and what part liquid chlorine as such has played in it, we do not know.

I have read only one report in one of the medical journals which seems to be entirely unbiased and therefore in fair accordance with the facts, free from newspaper sensationalism.

The report shows more or less severe affections of the breathing organs, so severe in some instances that it seems incredible, according to my experience, that they should have been caused by inhaling of chlorine gas. Of course, I do not doubt that chlorine can be very detrimental to the human system in a closed room, from which there is no escape, but in the open air with a wind blowing, no matter how gently, it seems next to impossible that any suffering beyond that of temporary coughing spells, vomiting, etc., could occur.

It has been suggested from various sides, and it is undoubtedly a fact, that the chlorine if employed is mixed with other ingredients, such as bromine, sulphur and others, which would cause more severe and more lasting irritations than chlorine alone. I know personally of one instance in which sulphur has been used in connection with liquid chlorine.

We naturally have had a long experience in this line, particularly at the start, when we had to struggle with a good many imperfections, leaks, etc., and never in any instance have we seen any lasting detriment suffered by any of our men.

I have also had several years' experience in Germany along the very same lines, and there also I have never been able to observe one single case of this kind. To appreciate this statement fully you ought to see into what kinds of atmosphere our men had to go sometimes without using any protection whatsoever, and when they had swallowed half of our production and were coughing violently they took a drink of Rexalls' A. B. C. seltzer or bromo seltzer and a few minutes later were back in the plant. These compounds, as well as any other of a stimulating or nerve relaxing influence, seem to be the best antidote for chlorine—among them a good stiff drink of whiskey.

If these are not available, inhaling of alcohol, chloroform or tetrachloride of carbon vapors spread out on a handkerchief will give speedy relief, but with the two latter ones one should be careful so that no narcotic effect may take place.

The inhaling of ammonia, which is recommended in several text books, should be absolutely rejected, because in most instances the irritation grows only worse instead of better.

Prevention is better than a cure, and the best prevention of inhaling too much chlorine is not to be afraid of it, and if a whiff of it gets into the nose, not to stop breathing abruptly. If you do and if you cannot get out of the room before you have to breathe again, you are bound to take a deep breath which will carry the chlorine to all the tender parts of your lungs and a violent coughing spell will be the result.

If, on the other hand, you continue to breathe—lightly, without taking a deep breath—you can stand a pretty strong chlorine atmosphere for minutes at a time, without any muzzle, safety helmet or other protection. Be careful, however, not to inhale the white fumes which are formed by ammonia and chlorine, in the course of trying to locate chlorine leaks with a rag soaked in ammonia. The coughing spells and the effect on the eyes caused by them are very much worse than with chlorine alone and last longer. Also wet chlorine such as emanates from a saturated chlorine water seems to have worse effects than the dry, although only slightly more so.

We have in our plant an oxygen safety helmet, but except for purposes of keeping our men trained in its operation, I have never seen it in actual use.

Another purpose for which undoubtedly quantities of liquid chlorine have been shipped abroad from this country is for the manufacture of picric acid, which, in this instance, can be made by first producing chlorbenzol, nitrating it, and then replacing the chlorine by hydroxyl by treatment with alkali.

These are the two only purposes for which, as far as I know, liquid chlorine has been used for war purposes. However, as you see, they are rather limited in their effects and, therefore, hardly deserving of the prominent place accorded them in the newspapers.

In general, I may say—and I hope I have been able to demonstrate it in this paper—that liquid chlorine is much more important for peaceful than for war purposes, and we are taking considerable pride in the fact that in the past few years we have been able—instead of causing destruction of human lives—to save them from the ravages of typhoid fever and in this way to prove that instead of being an enemy, liquid chlorine is becoming more and more a savior and a boon for mankind.

Recent Chemical and Metallurgical Patents

Gold and Silver

Sodium-Amalgam Precipitant for Cyanide Solutions.

—It is known that metallic sodium may be diluted with mercury so that it will replace various metals from their solutions, the metals thus displaced combining with the mercury. This principle is applied by HANS FOERSTERLING and ARTHUR L. HALVORSEN of New York City, in the patented use of sodium-amalgam for precipitating gold, silver and copper from cyanide solutions. The apparatus designed for applying the invention is shown in Fig. 1. It consists of cylindrical casing 1, of soft steel, an axis 2 bearing an inclosed drum 7 on which, at suitable intervals, are annular soft steel plates 8 having perforations 8a for the passage of solution. In the

The invention provides a cyclic process specially adapted to the treatment of complex sulphide ores containing such metals as lead, iron, copper, silver, gold, etc. The proper performance of the cycle depends on the presence of manganese, which may either be a normal constituent of the ore or added in the form of manganese carbonate or sulphide. The addition may be made either on starting or after the operation has been established. The function of the manganese is to serve as a carrier of oxygen to oxidize ferrous compounds to ferric, and thus make possible the complete separation of iron from solution.

Sulphide ores or concentrates are first roasted. Manganese is introduced subsequent to the roasting operation, and in such quantity as may be required by the ferrous iron to be oxidized. After roasting, the ore is leached with sufficient dilute sulphuric acid so that there is from 5 per cent to 10 per cent excess acid over the amount required to complete the reaction. The oxidized metals go into solution as sulphates, some of the iron as ferrous sulphate. In this state the iron is not removed by adding lime or zinc oxide, and it is for the oxidation of this ferrous iron that manganese in its higher forms of oxidation is used. It may be present in the form of manganese dioxide or permanganic acid and possibly other states of oxidation higher than the manganous. It may be present either in solution or suspension, according as it is soluble or insoluble.

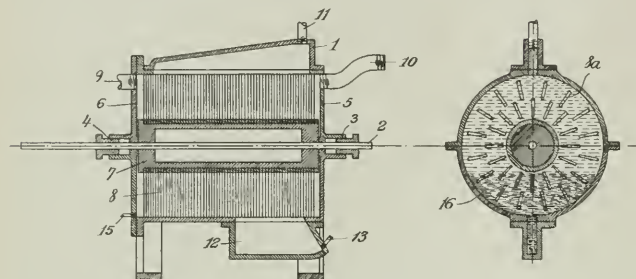


FIG. 1—SODIUM AMALGAM PRECIPITATING APPARATUS

upper part of the casings are pipes 9 and 10 for the inflow and outflow of solution, while pipe 11 serves as an exit for gases. At the bottom is a pocket 12 into which material can be introduced through pipe 13. The axis, drum and attached plates are adapted to revolve through a bath of sodium amalgam in the lower part of the casing, and carry thin films of amalgam upward through the solution flowing through the casing. As the metals are precipitated, cyanide is regenerated. The precious-metal amalgam can then be drawn off through pipe 15, while new supplies of sodium and mercury are added through 13.

Application to the precipitation of silver-bearing solution is illustrated thus: The solution contains 8.5 oz. silver and 0.095 oz. gold, 3.7 lb. free NaCN and 0.5 lb. Ca(OH)_2 per ton. As it passes through the apparatus at the rate of 100 tons per day, it comes in contact with the thin films of sodium amalgam on the plates and silver is displaced from solution and absorbed by the mercury. Sodium is fed at the rate of 90 lb. per day, and silver amalgam is withdrawn at a rate varying from 35 to 350 lb. per hour. Barren solution leaving the apparatus has a gold and silver value of \$0.07 per ton, and contains 4.1 lb. free NaCN and 1.7 lb. equivalent Ca(OH)_2 . The efficiency of the process is 99 per cent, since the gross value of the precious metals in the feed, with silver at 60c. and gold at \$20 per ounce, was \$7. The process is equally applicable to the recovery of copper from cyanide solutions. (1,164,636, Dec. 21, 1915.)

Zinc

Hydrometallurgy of Zinc with Electrolytic Deposition.—An insight into the methods to be used by the Anaconda Copper Mining Co. in the wet treatment of zinc ores and production of electrolytic zinc at Great Falls, Mont., may be had from patents recently granted to FREDERICK LAIST and FREDERICK F. FRICK, of Anaconda, Mont., members of the technical staff of that company.

In any event in these higher states of oxidation the manganese is a product of the final electrolytic stage of the process, and is returned to the proper stage for the oxidation of ferrous iron. Having oxidized all the iron, that metal can now be precipitated by milk of lime of zinc oxide. Iron, arsenic and antimony are thus precipitated. For the removal of copper from the electrolyte, and possibly small amounts of silver, arsenic and antimony also, zinc dust is added to the solution. At the stages of precipitation of the various impurities, decantation or filtration of the solution follows, and finally a pure electrolyte of zinc sulphate is obtained, containing manganese. This solution is then electrolyzed, using insoluble anodes, as of lead, and cathodes of zinc starting-sheets. The products of electrolysis are zinc, sulphuric acid and manganese dioxide and permanganic acid. The solution containing the sulphuric acid and manganese is now available for further leaching, oxidizing the ferrous iron and facilitating its removal. According to a modification, an excess of the roasted ore may be used for precipitating iron, arsenic and antimony; but since ferrous iron might also be added in this procedure, a certain amount of manganese dioxide derived from electrolysis is introduced at the same time. Since the roasted ore is used in excess for this precipitation, a small residue would remain, and this is to be mixed with raw ore in the roasting furnace, at which time the ferric hydroxide in the residue is converted largely to ferric oxide, which is insoluble, while the zinc is unaffected and may be dissolved. (1,167,700-1, Jan. 11, 1916.)

Removal of Cadmium from Zinc Ores.—In view of the greater value of spelter free from cadmium, for certain commercial purposes, it is desirable to free cadmium-bearing zinc ores from this impurity before smelting them for their zinc content. Mr. GILBERT RIGG, of Palmerton, Pa., proposes to accomplish this by heating the ore to a temperature of from 700 deg. to 850 deg. C. in an atmosphere of a reducing gas, such

as producer gas. The process may be performed in an inclined rotary cylindrical kiln, heated internally by the combustion of the producer gas. The ore enters at the upper end and discharges at the lower. Provision is made for regulating the supply of gas and air, so that when the temperature of the furnace tends to decrease, the supply of air may be increased to restore the higher temperature. In fact it may be found desirable to operate the process with alternately high and low temperatures within the range indicated.

According to a patented modification of the process, the ore may be supported on a suitable grate, either stationary or traveling, within a furnace structure, wherein provision is made for a down-draft through the mass. In such case the fuel would be on top of the layer of ore, and as the heat penetrated downward the cadmium would be volatilized and drawn off in the gases. Instead of placing solid fuel on top of the ore, an ignited mixture of air and producer gas could be drawn downward through the bed and the temperature be alternately increased and decreased within the indicated limits until the cadmium was removed. (1,161,885-6, Nov. 30, 1915.)

Aluminium

Production of Aluminium from Clay and Other Aluminium Silicates.—Fig. 2 illustrates the flow-sheet of a process for obtaining aluminium from its silicate combination, the method being patented by GRENVILLE MELLEN of East Orange, N. J. The clay or kaolin is fused with sodium sulphate and sulphuric acid, or with its equivalent of sodium bisulphate, in proportions to form aluminium sulphate and free silica. After the reaction is completed the mass is cooled and dissolved in hot water or in a hot dilute solution of sodium sulphate containing a small quantity of aluminium salts from a prior extraction. The hot solution thus obtained

is filtered and the filtered concentrated if necessary. At this stage a concentrated solution of sodium fluoride is added, precipitating aluminium fluoride, which is separated by filtration. The filtrate containing sodium sulphate is concentrated to crystallize the contained salt which is again used in the process. The aluminium fluoride is fused with sodium chloride and electrolyzed, producing aluminium. By-products are pure silica, chlorine and sodium sulphate. The process is cyclic, as seen by the flow-sheet. (1,160,431, Nov. 16, 1915.)

Melting Aluminium.—A new process for melting aluminium or its alloys, having for its object the protection and preservation of the metal from oxidation and the production of sound castings, is patented by GRENVILLE MELLEN of East Orange, N. J. In carrying out the process the metal to be melted is placed in a crucible in an air-tight chamber. The air is then removed from the chamber and an inert gas admitted. After the metal is melted in this inert atmosphere, and while the metal is yet molten, the inert gas is removed from the chamber, thus producing a partial vacuum therein. Occluded gas is thus removed from the molten metal, and it is then ready for pouring, which should be done as quickly as possible. (1,160,430, Nov. 16, 1915.)

Vanadium, Uranium and Radium

A process for extracting vanadium, uranium and radium from ores is patented by RICHARD B. MOORE of the United States Bureau of Mines, Denver, Col. The process is that which has been used by the National Radium Institute, Denver, and which has been referred to in this journal, Dec. 15, 1915, page 965, and Jan. 1, 1916. It is also the subject of *Bulletin* No. 104, Bureau of Mines. Reference is here made to the patents to record the fact that they are dedicated to the public and can be used without payment of royalty. (1,165,692-3, Dec. 28, 1915.)

Electrolytic Processes

Electrolytic Cell for Treating Ores.—A revolving electrolytic diaphragm cell for the hydrometallurgy of ores is patented by LEWIS E. PORTER of Los Angeles, Cal. (one-half assigned to Hugh E. Stock of Casper, Wyo.). The cell consists of two concentric cylinders, the inner one forming the cathode and being made of metal and the outer one made of wood and provided on its inside surface with a number of plates which act as anodes. These plates are connected to an outside slip ring and the cathode is also connected to a slip ring. The cylinders are both on the same shaft and the outer cylinder is geared to a driving pinion for revolving the cell. Surrounding the inner cathode cylinder and close to it is placed another wooden cylinder constituting a diaphragm containing a number of small perforations and over this a filter cloth is placed. The action of the cell is as follows: The anode chamber, which is the outside annular space, is filled with ore through a suitable opening and electrolyte nearly saturated with metallic salt is forced in under pressure, filling any spaces not filled by the ore and being forced through the diaphragm and filter cloth into the cathode space between the diaphragm and inside cylinder. The ore in contact with the plates on the inside surface of the outer cylinder forms the anode and solution takes place, with metal subsequently depositing on the cathode. The cathode cylinder has horizontal wooden strips on its surface which divide the deposited metal into several strips, making it more easily removable. Suitable pipes are arranged for conducting away any gases formed in the anode or cathode chamber and the anode chamber pipe is provided with a safety blow-off valve, in case of too great a gas pressure developing.

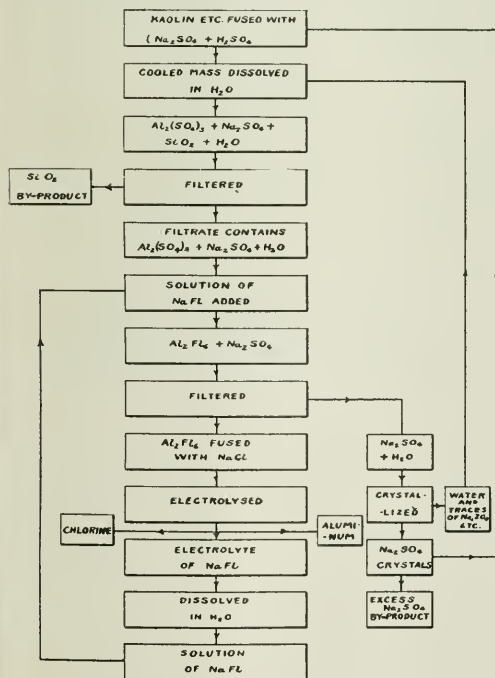


FIG. 2—PRODUCTION OF ALUMINIUM FROM CLAY

The cell is stated to be applicable to the recovery of zinc from zinc ores containing considerable iron. (1,167,594, Jan. 11, 1916.)

Non-Metallic Cathode for Sodium Chloride Electrol-ysis.—A cathode for use in diaphragm cells which is intended to prevent the deposition of calcium or magnesium salts, found as impurities in salt solutions is patented by FRANK McDONALD of Roaring Springs, Pa. This cathode is made of graphite and a form of cell illustrating the use of this cathode is shown in Fig.

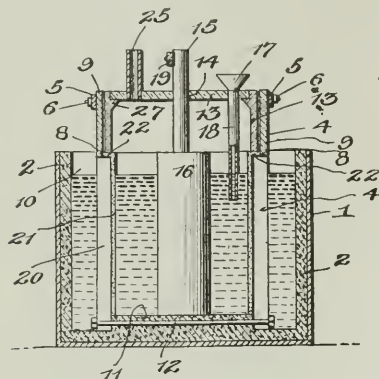


FIG. 3—CAUSTIC SODA-CHLORINE CELL

3. The tank or cell is cement-lined and the diaphragm is shown at 21 and the perforated graphite cathode at 20. The anode is shown at 16 and chlorine space inclosed above the anode space by slate cover 13 fastened to the cathode and diaphragm. Chlorine is conducted away through pipe 25 and caustic soda overflows from the outside cathode chamber through an outlet in the side not shown. The cathode and diaphragm are clamped to the raised cement projectory 11, and the cathodes are made porous by saw cuts in that portion which is below the solution. The diaphragm is of asbestos sheets. It is claimed that this cathode does away with the objectionable features of metallic cathodes in the use of which the internal resistance may rise owing to the deposition of non-conducting salts of calcium and magnesium existing as impurities in the salt solution, which would also clog the perforations of the cathode. (1,167,705, Jan. 11, 1916.)

Bismuth

Method of Purifying Bismuth.—A series of treatments forming a process for the production of pure bismuth is patented by WALTER C. SMITH of Chrome, N. J. (assigned to U. S. Metals Refining Co.) In the treatment four separate operations are performed as follows (not necessarily in the order given): 1. Sulphur is added to the molten impure bismuth metal while agitating and the temperature lowered to 515 to 520 deg. Fahr. By this treatment all of the copper and the greater portion of the tellurium, silver, arsenic, antimony, selenium and zinc, some of the tin and a fair portion of the lead are removed. The impurities form a matte which floats on top and may be removed. 2. Caustic soda is added to the molten metal and agitation commenced by steam. The caustic removes the tellurium, selenium, sulphur, arsenic, antimony, tin and zinc, forming sodium compounds which float on the surface. Silver and gold will be unaffected. 3. Zinc is added to the molten metal while agitating and the temperature lowered to about 550 deg. Fahr. This further

reduces the amount of silver present and removes all the gold. The remaining lead and practically all the remaining silver and any gold remaining are removed by crystallization. The steps may be modified or rearranged to suit conditions. (1,166,721, Jan. 4, 1916.)

Alloys

Electric-Resistor Material.—An alloy of nickel, copper and chromium to be used for electrical resistors is patented by MATTHEW A. HUNTER of Troy, N. Y. The alloy is stated to combine high resistivity with low temperature coefficient of resistance. The proportion of nickel used is large, relative to the copper and chromium and an alloy which has been found to give good results consists of the following: 85 parts nickel to 15 parts copper, with 20 parts chromium to 100 parts of nickel and copper. This alloy has a resistivity of 113 microhms per centimeter cubed at 20 deg. C., and at that temperature has a temperature coefficient of resistance of 0.000078 ohms per deg. C. per ohm. The copper increases the resistivity up to a certain point, and the chromium effects a reduction in the temperature coefficient of resistance. (1,168,074, Jan. 11, 1916.)

Copper Alloy.—An alloy consisting of copper, aluminium, antimony, iron and silicon is patented by WILLIAM C. PEASE of Marietta, Ohio. In making this alloy aluminium is first heated in a crucible, and while it is melting a piece of clay about the size of an egg per pound of aluminium is added. When this mass has thoroughly melted iron pyrite is added and stirred well. This is then poured off and broken into small pieces. One ounce of this mixture is added to 1 lb. of molten copper. The proportion of aluminium to iron pyrite is usually 16:2, although this may be varied. For further hardening the copper, antimony may be added. An average analysis of this alloy would be: copper, 88.4; aluminium, 6.6; antimony, 1.26; iron, 1.96; silicon, 1.60. It is claimed that the alloy may be molded, machined or forged. (1,168,962, Jan. 18, 1916.)

Electroplating

Continuous Electroplating Apparatus for Magnetic Material.—A continuous plating apparatus, designed primarily for electrogalvanizing pipes, rods, or other long, slender magnetic metal articles, is patented by NEWTON W. BUCH of New Castle, Pa. (assigned to Safety Armorite Conduit Co. of Pittsburgh, Pa.). A cross-section of this apparatus is shown in Fig. 4. The

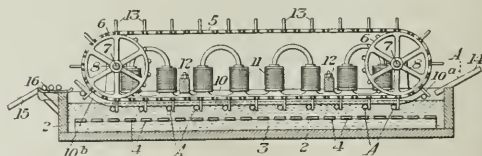


FIG. 4—ELECTROPLATING APPARATUS

tank 2 may be made of any suitable width to suit the work to be done. The electrolyte 3 fills the tank as shown and anode members 4 are arranged toward the bottom of the tank. An endless chain having protruding pieces 13 fastened to it revolving on sprockets as shown passes through the solution. Below this endless chain or belt and in the solution is cathode member 10, which is turned up at the ends in order to facilitate introduction and delivery of the material to be plated. The cathode members, one of which is placed parallel to the one shown on the other side of the tank, form pole pieces for electromagnetic coils shown at 11, 12, 13

are cross-bars for supporting the cathodes and magnetic coils. The material to be plated is introduced at 14, is passed through the solution by the moving chain while being attracted to the cathode on account of its magnetic force. The material is delivered at 16 by the protruding members of the traveling belt. (1,168,281, Jan. 18, 1916.)

Electroplating Apparatus for Plating Pipes.—An apparatus for plating pipes and other magnetic material is patented by NEWTON W. BUCH of New Castle, Pa. (assigned to Safety Armored Conduit Co. of Pittsburgh, Pa.). This apparatus consists of a large cell having stationary anode plates and cathode racks or lifting frames consisting of a number of magnetic coils, suitably spaced on parallel bars and forming a coherent unit which may be picked up by a crane or other lifting device. The articles to be plated are placed in a rack, the magnetic lifting frame is placed on them by the crane and the current turned on in the magnetizing coils. The articles to be plated are thus raised up and conveyed to the cell or tank where they are lowered into place and disengaged from the crane. The magnets still hold on to the articles while they are being plated, and when finished they are again removed and replaced in their former rack by releasing the current in the magnet coils. The advantages claimed are that rapid and efficient work can be done and in large quantities at a time, and the articles can be plated all over, as no mechanical holder covers up any space. (1,168,280, Jan. 18, 1916.)

Synopsis of Recent Chemical and Metallurgical Literature

Gold and Silver

Effect of Heat in Cyaniding Gold Ores.—The literature on this subject is scant and the data too general. In order to make a more careful investigation of the subject, Mr. E. A. WRIGHT has performed several series of experiments which he has recorded in *Bulletin* 135, Inst. Min. & Met. The first tests were made on a silicious gold ore containing about 7 per cent pyrites, and 4 oz. gold and 5 oz. silver per long ton. This ore was ground to pass a 60-mesh screen. It was agitated in duplicate quantities in hot and cold cyanide solution for definite periods. In the same manner a basic ore containing limonite and about half the gold and silver as the first ore. The ore was ground to pass 120-mesh. The results obtained from these ores indicated that agitation in a hot solution was of very doubtful benefit. In the first case the hot solution showed a better extraction than the cold for the first hour, but after that the hot solution was at a decided disadvantage. In the second case similar results were obtained, the hot solution giving better extraction for the first hour, but only equaling that of the cold solution at the end of four hours. In both cases, however, the consumption of cyanide was higher in hot solutions. In explanation of the results the author cites the fact that the solubility of gold in cyanide solution increases up to a certain temperature, beyond which there is a decrease. Further, the solubility of minerals like pyrite, in cyanide solution, increases with the rise in temperature, and probably the increased solubility of base minerals counterbalances the solubility of the gold, resulting in a greater loss of cyanide and a consequent decrease in gold dissolution.

Further experiments were made with heated air for agitation, using air at a temperature of about 350 deg. C. The results of these tests showed that while the hot air accelerated the rate of extraction, it did not give

as high a total extraction as under cold conditions. The acceleration noted is probably due to the increased activity of the oxygen, an idea which is apparently confirmed by experiments with hydrogen peroxide added to cold solution to supply oxygen in an active form. Other oxidizing agents, such as potassium bichromate and permanganate, were tested, with decidedly deleterious action.

The author concludes:

1. The effect of heating cyanide solutions is of very doubtful benefit; the extraction may be increased for a short period, but this is more than compensated by the increased cyanide consumption and the subsequent decrease in the rate of dissolution of gold.

2. Oxidizing agents (H_2O_2 excepted) are apparently of no value and may even exercise a deleterious effect on the extraction.

3. The addition of oxygen in a more active form, either as hydrogen peroxide or by means of heated air, increases the solvent activity of cyanide solutions in a very pronounced manner.

Copper

The Role of Sulphur in Pyritic Smelting.—In the course of his address as president of the Australasian Institute of Mining Engineers, Mr. Robert C. Sticht made the following remarks relative to the fuel value of sulphur in smelting at Mount Lyell. The complete address appears in the Institute *Proceedings*, No. 19, 1915:

"On its downward course the 'pyrrhotite' suffers a further desulphurization in the preparatory zone, in the hot current of neutral gases, under the influence of increasing temperature. It progressively loses more and more of its sulphur, until the particular combination of iron and sulphur, which finally reaches the focus, is even lower in sulphur contents than the monosulphide, FeS. Its composition naturally greatly varies, but for practical purposes it may be regarded as a solution of a little metallic iron in the monosulphide. Empirical formulae, like $4FeS$, Fe , and $3FeS$, Fe , are commonly indicated as representative of this residual sulphide when the working of the furnace is investigated by calculation.

"I do not, however, regard this high desulphurization as an advantage, but rather as a defect of our work—not on account of the possible liberation or precipitation of metallic iron in quantity, and the formation of 'sows' (a phenomenon which has never been observed at Mount Lyell), but because the particular sulphur and iron compound which thus reaches the focus is the one that does all the work there, and, under the circumstances, the shortage of even the small amount of sulphur involved is a drawback. It has not yet been possible to regulate the composition of the sulphide that burns in the focus, and it is possible that, if we could currently burn a composition more like FeS there, the small amount of coke which it is still necessary to use to furnish up the general furnace heat might be curtailed, or altogether avoided. The point seems rather fine, and the endeavor savors of splitting hairs, but it is certainly inaccurate to take it for granted, as is usually done, that it is FeS that burns in the focus, when it is actually a less energetic compound.

"From the foregoing it will be obvious that the sulphur in the original pyrites does not contribute very vitally to the heat developed in the pyrite furnace, notwithstanding its great quantity. The Mount Lyell pyrites now commonly has about 46 per cent of sulphur, and the North Lyell ore has 7.5 per cent. The ordinary furnace mixture of the two has about 30 per cent S.

Yet, of the original total S in the FeS, treated (*i. e.*, not counting the sulphur protecting the copper in its passage through the furnace), only 36-38 per cent actually is burnt in the focus as a fuel. A bare 2 per cent of the total goes into the matte, and from 55-60 per cent of the original S in the FeS, distills out of the furnace as sulphur vapor, without combustion anywhere, except in the shaft above the column, where it comes into contact with the atmosphere. The temperature at the throat is high enough to ignite it. These figures indicate the loss of a very considerable portion of the total inherent fuel value of pyrites.

"Unfortunately, there is no hope of realizing the calorific value of the sulphur thus escaping from the depths of the furnace, for the volatility of the vapor cannot be restrained, and the preferential affinity of the oxygen in the blast for the iron also discriminates against the combustion of the metalloid. Of the metal, iron, the furnace oxidizes quite regularly 95 per cent of the total contents in the ores. By contrast this represents a very valuable utilization of a constituent which is present in smaller quantity, and also has a lower calorific value, than the sulphur, for it saves the situation.

"There is, similarly, no prospect of utilizing any portion of the loose (*i. e.*, volatile) atom of sulphur out of the pyrites, which at once sublimates off at the throat. The suppression of all these eliminations would only be possible if the tension of the furnace atmosphere could be sufficiently increased to counteract the vapor tension of the subliming sulphur. This, however, is beyond the reach of our pressures, and impracticable in our apparatus.

"Were it feasible to burn the original FeS, in its entirety to the same degree as the Fe alone is now burnt, then the cokeless smelting would be accomplished. But it would have to be done in an apparatus differing very considerably from our present blast-furnace (or converter), and it is not easy to forecast the constructional lines of a closed, high-pressure structure, which it would have to show. It would have to embody all the accessibility of the throat for feeding and barring which the blast-furnace presents, together with a sealed tunnel-head, and at the same time be as simple to handle as our blast-furnaces now are. On the other hand, the mere raising of the blast-pressure in the existing furnaces will not lead to the combustion of noticeably more of the sulphur. Unless the ore column is simultaneously increased, a very heavy blast will only cause a waste of wind, by escape from the top, and the formation of a low-grade matte, owing to the lack of preparation of the descending masses in consequence of the rising of the focus. Some of the escaping sulphur may be burnt in such a case, but this will be above the stockline. Such back pressure as can be arranged for in the present furnace construction by means of tight charging-doors, etc., is insufficient to keep down the sulphur to any extent, and inadequate to force it to remain fixed until it gets to the focus in greater proportion.

"Something was hoped for in this general connection from the increase in height of the Mount Lyell furnaces. The column used to be 10-12 ft., and may now be carried up to 18 ft. No palpable effect has so far resulted from our efforts to cut down the coke and burn proportionally more of the sulphur. It must, however, be explained that just about the time the column was raised the percentage of Fe and S in the Mount Lyell pyrites began to decrease, while the Zn and Pb increased, and this change of composition has since become permanent. It has had an unavoidable deleterious effect on the heat developed by the charge alone, and, instead of being able to lower the coke, we have been obliged to raise it.

We are satisfied, however, that, with the former lower column, we would be obliged to use still more coke, for the same blast volume."

Crushing and Grinding

The Dumb-Bell Tube Mill.—In the *South African Mining Journal*, Nov. 13, 1915, Mr. G. A. ROBERTSON describes a new type of tube mill. Instead of using pebbles as grinders it contains a roller of dumb-bell shape. The mill tested was 3 ft. 6 in. long and 2 ft. 9 in. in diameter. The roller has its weight concentrated at the two ends, and each end has a concave face which fits two convex faces in the shell of the mill. As motion is imparted to the mill the roller revolves, and when ore is fed it becomes ground between the faces described. Both ends of the mill are the same, and it can be fed and discharged from both ends simultaneously. The dumb-bell mill is equipped with centrifugal classifiers fitted into the trunnions at each end. These classifiers revolve with the mill, and all particles of sand which drop into the pockets of the classifier are returned for further grinding. The following is a record of two tests made at the May Consolidated, using a sand feed of +0.0249 in.:

Mesh	Intake, Per Cent	Discharge, Per Cent	Mesh	Intake, Per Cent	Discharge, Per Cent
+ 30	3.5	—	+ 30	7.3	—
+ 60	29.5	0.5	+ 60	33.3	12.3
+ 90	19.2	22.9	+ 90	16.8	28.4
+ 200	12.5	22.8	+ 200	10.9	14.7
-200	35.5	55.8	-200	31.7	44.6
	100	100		100	100

Moisture, 92.3 per cent.
Duty per 24 hours, 5.2 ton.

Moisture, 90.4 per cent.
Duty per 24 hours, 6.5 ton.

The following figures show the mill's performance when fed at both ends and discharging at both ends. The feed passed a screen of 0.03-in. aperture:

Test	Screen	Per Cent		Moisture in Feed Sample, Per Cent	Duty Per 24 Hours, Tons
		Inlet	Outlet		
(1)	+ 60	31.4	11.1	75	16.5
	+ 90	16.5	24.1		
	- 90	52.1	64.8		
(2)	+ 60	24.7	15.6	Full battery water.	25
	+ 90	16.7	22.0		
	- 90	58.6	62.4		
(3)	+ 60	42.1	30.2	60	13.5
	+ 90	21.5	27.0		
	- 90	36.4	42.8		
(4)	+ 60	42.8	16.9	75	14.5
	+ 90	18.7	33.4		
	+ 200	12.2	16.7		
	-200	26.3	33.0		

In order to determine the performance of the mill with coarse feed, it was fed with material $\frac{1}{2}$ in. + 0.03 in. with the following results:

	Inlet	Outlet
+ 30	67.5	15.5
+ 60	18.5	40.5
+ 90	5	15.5
-90	9.0	28.5

Duty 7 tons per 24 hours.

It is estimated that 4 hp. will drive this 3-ft. 6-in. by 2-ft. 9-in. mill at 40 r.p.m. The capital expenditure is small and the wear is confined to the convex and concave faces of the shell and roller. The water line is practically a horizontal plane. Grinding is done both by impact and compression. The designer believes that the size of feed can be increased as the weight of roller increases.

The Mojave Tungsten Company, recently formed, is preparing to operate two developed, four partially developed, and several undeveloped claims in San Bernardino County, California. A modern concentrating mill will also be erected which may be used for custom purposes as well as for the company's own use. Several well known men are identified with the new company.

High Temperature Insulation

A Paper Read Before The Chicago Section of the American Society of Mechanical Engineers on January 14, 1916

BY P. A. BOECK

The problems of conservation of heat and prevention of thermal losses have been the subject of considerable investigation and research in certain industries, more especially in the application of cold-storage installations for low temperatures, and of steam lines and electric furnaces in high-temperature work. It has not been until recently, however, that this subject as applied to general industrial purposes, has received the attention of designers and engineers that its importance deserves.

Heat flow is a rather difficult factor to measure under the working conditions of an industrial furnace. It was not until the comparatively recent introduction into certain operations of the heat balance sheet, with a systematic attempt to account for the discrepancies in the totals, that the various causes of heat losses and the reasons for their existence were brought to light. Moreover, such rapid advancement and radical changes in the design of equipment, especially in metallurgical lines, have occurred that practice has apparently out-distanced the theory of design. In the modern tendency toward greatly increased size of units, effort has seemingly been made to utilize the heat of fuel gases without proper attention having been paid to conserving heat energy and confining it strictly to the points of maximum activity.

The work of several of the Government Bureaus, notably that of Bureau of Mines and Bureau of Standards, and the systematic investigation of the thermal properties of structural materials by a number of the technical societies are forming the basis for more intelligent and consistent work in the economically important subject of the prevention of fuel waste. We would refer to the recent excellent paper of L. B. McMillan¹ before this society. Here the point is made that it is not alone the efficiency of the insulator nor its initial cost, but a factor consisting of both of these items, together with the factor of durability or permanence, which form the ultimate criterion of the most effective insulator for any specific purpose.

¹L. B. McMillan: The Heat Insulating Properties of Commercial Steam Pipe Coverings, Transactions of the American Society of Mechanical Engineers, 1915.

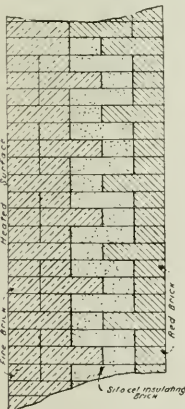


FIG. 1 — TYPICAL WALL CONSTRUCTION WITH SILOCEL BRICK LAID IN WALL

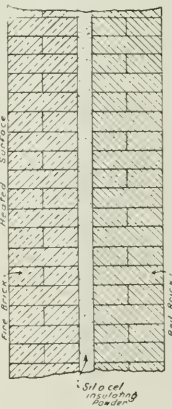


FIG. 2 — TYPICAL WALL CONSTRUCTION WITH SILOCEL POWDER IN HOLLOW WALL

It should be unnecessary in this practical and utilitarian age to call attention to the need of preventing heat losses, but the consistent and intelligent application of insulation to high temperatures has brought out other advantages in addition to the saving in fuel. The most important of these advantages from an industrial point of view, is that of increasing the furnace capacity, it not being uncommon to add as much as 10 to 15 per cent to the furnace capacity without increasing the size of the equipment, the fuel consumption and overhead expense.

This is more evident when dealing with higher temperatures, considering that no matter how much fuel is consumed to produce a given product, the results are not obtained until the temperature attained is high enough to bring about the reaction. Any increase in the temperature and heat capacity of the equipment above that necessary to get results, produces an increase in output equivalent to many times the actual temperature difference.

The insulation of hot-blast stoves, for instance, is being advocated for the heat saved. This is a large and important factor which has been frequently brought out, but it is of minor importance when compared with the advantages of increased tonnage produced. Therefore, when the reference is made in this discussion to heat saving and increased capacity, we have in mind the effect of adding increased energy at the point of maximum effectiveness without additional fuel.

ADVANTAGES OF INSULATION

In any high-temperature apparatus if the heat can be prevented from being dissipated from the outside of the furnace, the temperature of the furnace is made more uniform and the zone of the reaction and consequently the capacity, are manifestly increased without additional fuel consumption. Furthermore, overheating at the source of heat in the effort to bring as much of the furnace as is possible into the zone of reaction, is materially reduced by preventing the loss through the furnace walls. This has the ultimate effect of lowering the temperature at the source of heat, greatly increasing the life of the refractories and the capacity of the furnace.

It is evident also, that in furnaces which are surrounded by metal casings, deterioration and damage caused by overheating may be many times as great as

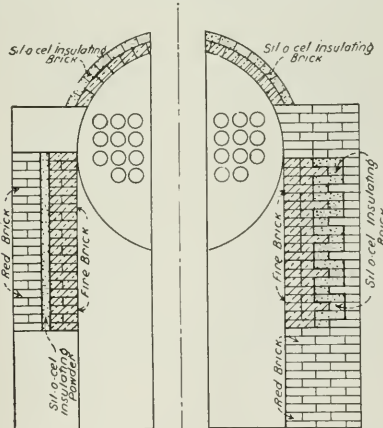


FIG. 3—INSULATION OF BOILER SETTING BY MEANS OF SILOCEL BRICK AND POWDER

the cost of installing the proper insulation. The advantages gained by the protection of workmen from unhealthy and unsanitary conditions, incident to their laboring under over-heated conditions, are also apparent.

In general then, the question of insulation does not concern itself so much with the saving in fuel, which, of course, is an important item, as with the *general effect produced by confining the heat generated to points of maximum effectiveness*. The higher the cost of fuel, the more necessary it is to look closely to the preventable losses to gain an economically operated furnace.

HEAT FLOW

Inasmuch as the amount of heat conducted by a body is one of the principal sources of loss in high-temperature equipment which we have under consideration, it will be of interest to inquire into this in order that we may control the flow of heat by this method as far as possible. Heat is a form of energy consisting of molecular vibration of a periodic character, and subject to the general laws of wave motion. It can be reflected, refracted and dispersed by creating the proper conditions. In other words, by the proper mechanical manipulation we can increase or decrease, within certain limits, the amount or rate of heat flow. One of the most common ways of doing this is by introducing alternate layers of materials having different heat-transmitting values, thus breaking up or changing the wave length. The introduction of air cells or voids within the body is a most effective method of accomplishing the reduction of the conductivity. In fact, the apparent density of a body (which indicates the proportion of voids present) may be taken as an approximate criterion of its heat conducting capacity, i.e., the body is made more opaque to the propagation of heat vibration. This, however, is more apparent where the size of the voids are very small and the number great. Large voids have the effect of propagating heat by convection and radiation as will be seen later.

Heat is transferred from one place to another by three different methods, conduction, radiation and convection:

Conduction.—Conduction is the action taking place in the transfer of heat in which the heat energy is passed along from a particle at a higher temperature to a lower one by virtue of their contact. While this method of heat transfer applies to the three states of matter, it is only of magnitude in solids.

Radiation.—By Radiation heat is transferred from

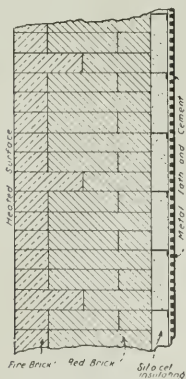


FIG. 4 — TYPICAL WALL CONSTRUCTION SHOWING SILOCEL POWDER SUPPORTED BY METAL LATH, CEMENT FINISH

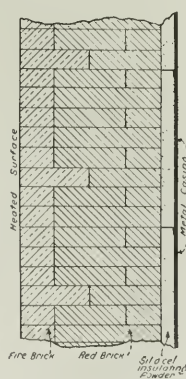


FIG. 5 — TYPICAL WALL CONSTRUCTION WITH SILOCEL POWDER SUPPORTED BY METAL CASING

one body to another without any material agency by wave motion; this applies only to the gaseous state of matter.

Convection.—Convection is that process of heat transfer in which some portion of the body whose temperature is raised, moves to another place in the medium where the temperature is lower, thus tending to raise the temperature of the medium. This method of heat transfer is therefore limited to liquids and gases.

STEAM BOILER

This is illustrated by the well known example of a steam boiler.² The heat generated by the fuel burning in the firebox is imparted to the dry surface of the boiler plate by radiation from the hot fuel bed, furnace walls and luminous flames, and secondly from the moving gaseous products of combustion by convection. From the dry surface it travels through the soot, metal and scale to the wet surface purely by conduction and is in turn transmitted into the boiler water mainly by convection.

The energy in the form of heat which eventually finds its way into the water in the boiler is, of course, subsequently available in other forms. That portion, however, which is transferred to the walls of the furnace setting by any of the three methods mentioned, is conducted through the setting and lost by radiation or convection from the outer surface of the setting, if means are not provided to prevent. It is the heat lost in this manner and methods for its prevention that will be especially considered in this discussion.

The selection of a boiler setting to illustrate the various methods for heat propagation was taken as that most familiar to general practice, but the selection is, unfortunately for the illustration, one in which the heat losses through the settings are comparatively low.

RATE OF HEAT FLOW

The rate of transfer of heat under various conditions, by both conduction and radiation, shows the relative importance of these two methods in influencing heat losses.³ The amount of heat conducted through a unit area from one part of the body to another is proportional to the difference in temperature of the two parts; directly proportional to the thermal conductivity of the body through which the heat passes and inversely proportional to the distance between the two parts of the body. In other words, the conduction of heat through a solid body from one place to another is a direct function of the conductivity of the body and the difference in temperature of the two planes, and an indirect function of their distance apart.⁴ This is identical with Ohm's law for transfer of electrical energy.

RADIATION

The heat transferred from one body to another by radiation is proportional to the difference of the fourth powers of the absolute temperatures of the two bodies. While this is strictly true only of the ideal "black-bodies," the variation is so small that for all practical purposes, this relation holds good in ordinary procedure.⁵

HOLLOW-WALL CONSTRUCTION

This relation indicates why a hollow-wall space is an effective insulator in low-temperature work, such as re-

²Kreislinger, Henry, and Ray, Walter T.: The Transmission of Heat into Steam Boilers, Bulletin No. 18, U. S. Bureau of Mines (1912).

³Convection and Radiation of Heat, Irving Langmuir, Transactions Am. Electrochem. Society, Vol. 23, p. 299 (1913); METALL. & CHEM. ENG'G, Vol. 11, p. 278 (May, 1913).

⁴Ray, Walter T., and Kreislinger, Henry: The Flow of Heat Through Furnace Walls, Bulletin No. 8, U. S. Bureau of Mines (1912).

⁵Gurney, Harold P.: Heat Radiation, Journal of Ind. and Eng. Chemistry, Vol. III, No. 11, p. 807, Nov., 1911.

frigeration, etc., whereas in high-temperature operations the loss of heat by radiation through a hollow-wall space is so great that its insulating effect is less than if this wall space were filled with material of rather high thermal conductivity. This has been brought out by Ray and Kreisinger who demonstrate that the hollow-wall space type of wall construction is much less effective as a means for preventing the loss of heat than a solid wall of any ordinary construction material of equal thickness. This is especially true if the air space in the hollow wall is near the furnace side and becomes highly heated. This is entirely contradictory to the general belief that, since air is a poor conductor of heat, air spaces built into the walls of a furnace will greatly reduce heat loss by radiation. While the heat does travel very slowly through the air by conduction, it leaps over the air space readily by radiation, because the quantity of heat which passes across the hollow space is a function of the fourth power of the absolute temperatures of the surfaces inclosing it, which loss is enormously increased by rise in temperature.

FURNACE WALLS

In general, in high-temperature furnace construction, there are two separate and distinct factors, which must be considered to produce an effective wall.

The first of these is to provide a material having the ability to resist the action of high temperatures, sufficient mechanical strength, and, possibly, the property of resisting corrosive slags, gases, etc., without spalling or being eroded.

Secondly, to prevent the excessive loss of heat due to conduction from the interior of the furnace to the outside where it is lost.

It is rare that a good refractory material is an insulator; usually it is necessary to augment or back up the refractory with some material having a much lower heat-conducting capacity.

REQUIREMENTS OF INSULATORS

The requirements of the insulating backing for the more refractory lining are rather severe. An ideal material would have the following properties: It should have an extremely high insulating value, and be sufficiently refractory so that no fusing or excessive shrinkage would take place in that portion which is in direct contact with the highly heated refractory wall. It should not be decomposed or be changed greatly in volume at the temperature, and it should, furthermore, be of light weight, unaffected by moisture, of convenient form, readily applied by unskilled labor, and low in cost. It should be of such composition as not to react upon or attack either the refractory material or the metal shell of the container, even in the presence of moisture; i. e., it should contain no free acid radicals, and should not be broken or caused to settle by vibration or heat. It should not have high expansion and it should be sufficiently elastic to take up strains between the lining and the shell produced by temperature changes.

While this is a rather formidable array of requirements, there are products upon the market which fulfill practically all of them. Such materials as are being commonly applied to steam-temperature insulation, of which magnesia and asbestos are best known, are, of course, eliminated from consideration in the great majority of cases mentioned here on account of decomposition, shrinkage and settling. The lack of more extended practice in high-temperature insulation must be attributed to the fact that effective high-temperature non-conductors have not been generally available.

AMOUNT OF INSULATION

When the kind of refractory material that is best suited to the surface has been determined, the next

most important item is the thickness of the walls and the nature of the insulating material most suitable, and it is necessary to determine the degree of insulation which will produce the most effective results.

Hering has pointed out that, in order to effect a perfect insulation, the furnace should be surrounded with an insulating material that would maintain the same temperature at any point as that of any adjacent point of the lining.⁶

In attempting to obtain perfect insulation, it is entirely possible to over-insulate, causing a serious damage to the refractories in the high-temperature zones of the furnace. To maintain the inner walls, it may be necessary to permit a considerable flow of heat through the wall, with a corresponding decrease in the temperature of the refractories at the heated point, in order to prevent their destruction.

It would be manifestly impracticable to insulate the roof of an electric steel furnace or open-hearth furnace, for instance, with a heavy layer of insulating material, because the cost of the refractory lining which would be destroyed would be considerably greater than the cost of the heat which would otherwise be lost.⁷

However, the issue in some instances may be met by other practical methods such as increasing the working capacity of the unit in order to make use of the additional heat available, rather than to let this valuable heat at the critical period escape to save the refractory lining. In calcining celite, the product which we will consider further in this paper, the temperatures are controlled entirely by the working load imposed on them

without allowing the oil burners to ever fall below their lightest working capacity and highest heat. To produce celite calcined to 2500 deg. F., an average kiln has a daily capacity of about 20 tons. When celite is wanted which has been calcined at 2000 deg., the kiln is pushed

⁶Hering, C.: Thermal Insulation of Furnace Walls, *Metallurgical and Chemical Engineering*, vol. x, No. 2, p. 97 (Feb., 1912).
⁷Lyon, D. A. Keeney, R. M., and Cullen, R. F.: The Electric Furnace in *Metallurgical Work*, Bulletin No. 77, U. S. Bureau of Mines (1914).

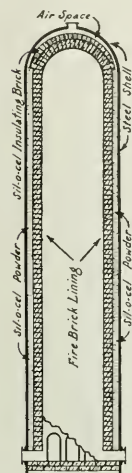


FIG. 6 — HOT-BLAST STOVE INSULATED WITH SILICOCEL POWDER AND BRICK

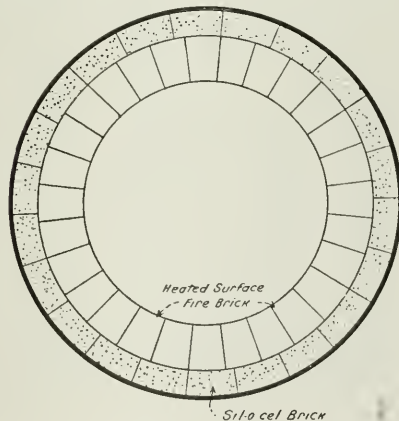


FIG. 7—HIGH-TEMPERATURE FLUE INSULATION

to approximately 30 tons capacity and for a product treated to even less heat, the capacity is increased as high as 40 tons, the heat being the same in all cases.

In electric-furnace practice, where extremely high temperatures are encountered and where effective insulation is necessary because of the relatively high cost of current, the question of insulation, or rather over-insulation, has been given more attention than in other lines. F. T. Snyder⁸ has presented a detailed study of the nature and amount of insulation which is permissible under various conditions and presents many valuable data which might with advantage be applied to other industries.

DESCRIPTION OF CELITE

The requirements of an ideal insulator have been outlined, and in order to show the various methods of application which have been worked out, it will be well to select the insulator which apparently most nearly meets the requirements and use this as an example of methods of construction. In the applications shown, an attempt was made to cover as wide a field of use as possible, to show the scope of possible applications.

The mineral known as celite, on account of its extremely cellular nature, is a mineral of a highly siliceous composition and of very light weight, which occurs on the Pacific Coast⁹ in an exceptionally pure state. It is composed of numerous hollow cells, and weighs in its natural rock-form, air dried, from 25 to 30 lb. per cubic foot. When this material is ground properly, it weighs but 8 lb. to the cubic foot, and has a thermal insulating power of about 9 to 12 times the insulating power of ordinary firebrick. In other words, a 1-in. layer of this material is the equivalent in insulating value of from 9 to 12 in. of firebrick. Being almost pure silica,

⁸F. T. Snyder: *The Flow of Heat Through Furnace Walls*, Transactions of the American Electro-Chemical Society, vol. xviii, p. 235 (1910).

⁹Deposits worked by the Kieselguhr Company of America, New York, Chicago, San Francisco and Los Angeles. See the article by the author in *Metallurgical and Chemical Engineering*, vol. xii, p. 109; Feb., 1914.

its melting point is high, 2930 deg. Fahr. (1610 deg. C.), as reported by the Bureau of Standards, and it can be subjected to high temperatures without fear of alteration.

⁹It has been found advisable, however, not to use celite as a refractory at extremely high temperatures without some direct protection. This is readily accomplished by using it as a backing material for more refractory and highly conducting bodies. Owing to its remarkable non-conducting properties, the accumulation of heat on its face is so great due to the fact that the surface is not cooled by conduction, that a "flash" of flame or gases might easily exceed the melting point of silica and cause failure. If it is protected, however, only modified and uniform temperatures are encountered, which are maintained without damage.

It is possible further to prepare bricks and blocks of various sizes and shapes by sawing the natural material by means of gang saws. Standard 9-in. straight silocel brick made from natural celite weigh from 1½ to 2 lb. each and are equivalent in insulating value to many times their thickness of ordinary firebrick. In crushing strength these bricks withstand over 400 lb. per square inch, and are sufficiently strong to stand transportation and handling.

The high insulating value of silocel bricks can be shown by applying the heat of a blast lamp or torch upon their surface for hours, the unheated surface remaining cool enough to allow handling with ease. Powdered silocel can be tested in the same way by packing it into a shallow paper box of convenient size.

The cost of these insulating bricks is but little more than that of firebrick and that of the powder about one-third as much, so that the first cost of insulation is comparatively low. In fact, instances are on record where the entire cost of insulation has been saved in fuel in the first few months of operation, leaving the gain in equipment efficiency and increased output or capacity as a clear profit.

TYPICAL WALL INSULATION

Because of the variation in forms in which silocel products are supplied—that of brick, blocks of various shapes, in powdered form and as a plastic cement—this material is adaptable to almost any form of thermal insulation, as will be shown in the following typical examples:

GENERAL TYPES

In general, there are four forms of construction for high temperature insulation which can be adapted to almost any character of equipment.

Fig. 1 indicates the usual method of using silocel brick interlaid between a course of firebrick and red brick for the prevention of heat leakage through walls. This form of construction is largely used in boiler settings, bakers' ovens, reverberatory furnace walls and roofs, etc., and is generally applicable where a strong, solid non-conducting wall is desired. Metal bonds can, of course, be used if desired, and the insulating brick built up in a uniform course.

Fig. 2 indicates one of the methods of construction of an insulating wall in which an otherwise hollow space is filled with insulating powder. From 2 to 4 in. are usually sufficient. The powder is packed slightly to a density of approximately 12 lb. to the cubic foot, at which point it attains its maximum insulating value and is not subjected to settling or contraction due to either vibration or heat. Where this form of construction has been in severe service in high-temperature furnaces for a period of years, no contraction or settling has taken place.

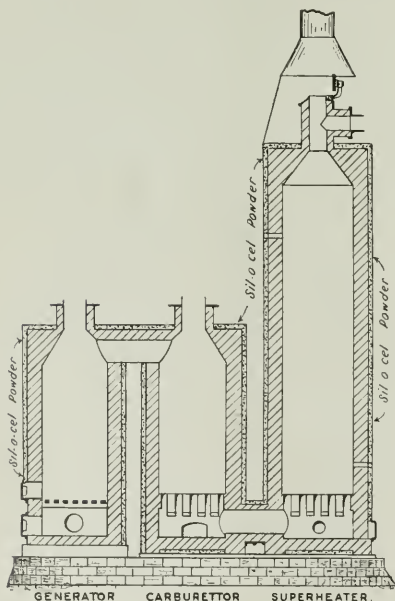


FIG. 8—GAS GENERATOR SET INSULATED BY MEANS OF POWDERED SILOCEL

Fig. 3 illustrates the insulation of a boiler setting by means of silicel powder in hollow wall (left hand of diagram) and by means of silicel insulating brick (right hand and top of diagram).

Figs. 4 and 5 indicate the methods of insulating brick walls which are already in place. This form of insulation can be applied to old construction as well as new. In this method expanded metal lath is erected on an angle iron at the required distance from the outer wall and coated on the outside with one or more coats of Portland cement plaster, to which a small amount of silicel powder, approximately 20 per cent by volume, has been added to give greater plasticity and ease of working and to increase the heat-resisting properties of the cement. Silicel powder is packed to a density of 12 to 15 lb. per cubic foot between the brick wall and the expanded metal lath. This form of construction is relatively inexpensive and allows of as much insulation as is required, and furthermore gives an absolutely permanent surface of excellent appearance, which can be applied to almost any character of equipment.

INSULATION OF HOT-BLAST STOVES

Hot-blast stoves (Fig. 6) and mains (Fig. 7) serving a blast furnace give an interesting application of high-temperature insulation, a number of these having been insulated in the Pittsburgh and Cleveland districts with excellent results. The detailed figures relating to the increased capacity and the thermal data are being compiled and will form the subject of another paper. At the present time, complete figures are not available.

Both insulating celite brick and celite powder have been used for this purpose with apparent equal beneficial effect.

The advantages derived from the effective insulation of stoves and high-temperature flues have been pointed out by Maccoun, Johnson, Mathesius, Wysor and others, it being estimated that preventable heat losses from surface radiation varies from 8 to as much as 20 per cent.

Hot-blast stoves provide an excellent example of the requirements of an insulation for high-temperature work, not so much because of the high temperature to which they are subjected, but more especially because of the size, expansion and contraction of lining and shell, settling, shrinkage, elasticity and corrosion of the insulator and protection of the shell itself, the constant change in temperature and other factors.

In a 20 x 100-ft. stove, for instance, the column of brick in the lining may expand through heat as much as 5 or 6 in. in height from cold to maximum heat.

Therefore, the insulator may be considered at all times being subjected to a certain amount of stress and friction requiring an elastic medium which will take up these continued strains without injury or danger of being crushed which would result as is the case of granular slag in constant settling, the accumulation of fine material causing occasional bulging of the shell at the base of the stove on account of its inelastic nature. Two principal requirements of the insulator are, then, elasticity with still sufficient strength to give the proper support to the brickwork and shell, and, secondly, the proper amount of cohesion or high internal coefficient of friction and light weight as to overcome any tendency toward settling under the movement or vibration of the stove.



52-IN. MAGNET LIFTING SCRAP CAST-IRON COLUMN WEIGHING ABOUT 8 TONS

Lifting Magnets of Large Capacity

The lifting magnet has been adapted for the handling of materials in all branches of the iron and steel industry and has exerted a great influence in reducing the cost of handling many materials. Magnets designed for large lifting capacity in handling raw material have been placed on the market by the Cutler-Hammer Clutch Co., Milwaukee. These magnets are known as "High Duty" magnets and are designed especially for handling raw material. Recent improvements have increased the lifting capacity from 20 per cent for some sizes up to 60 per cent for others.

They are made in various sizes ranging from 18 in. to 62 in., the approximate lifting capacity of the 62-in. magnet being 4000 to 4500 lb., while in certain cases where a good surface is afforded the magnet will lift as high as 60,000 lb. Under adverse conditions the lifting capacity may drop to 2000 lb. For the 62-in. magnet a current of 72 amp. at 220 volts is required.

The frame or body of the magnet is made of a special grade of dynamo steel. The coils in the very small magnets may be made of wire, but for the larger magnets the highest space efficiency is obtained by constructing the coil of alternate turns of copper strap and fireproof insulating ribbon. The spool is of steel and forms a part of the inner pole. An absolutely tight

joint between spool and magnet case is obtained, thus eliminating all dead air space and facilitating rapid radiation of heat. It is necessary to design the magnet so that the heat of the coil may be quickly and easily conducted to the outside of the body from which it is radiated. This is effected by removing dead air spaces.

Another feature of the magnets is their waterproof construction. This is accomplished by first fully assembling the magnet, and when all parts are in their proper position, it is subjected to a baking process which is continued until all traces of moisture in the interior of the magnet have been eliminated. Air is next exhausted from the casing and a hot liquid filler is forced in under pressure, which presently hardens. One of these magnets was successfully operated 70 ft. below surface in the Mississippi River.

The magnets handle heavy castings, scrap, pig, and a great variety of other material.

Simplifying the Ore-Crushing Process

Simplification in all departments of ore treatment is noticeable in modern design and construction of machinery and plant. In the field of crushing and grinding we observe the simple ball and pebble mills for fine grinding, while for intermediate or secondary crushing there is a tendency away from the use of the small jaw or gyratory crushers or large rolls. These latter machines lose capacity rapidly as the required fineness of their product is increased, and they are readily choked by overfeeding. An efficient substitute for these machines is found in the Symons disk crusher, made by Chalmers & Williams, Chicago Heights, Ill., who present the following data from an investigation by Robert S. Lewis of Salt Lake City, Utah.

In the field of intermediate or secondary crushing, meaning the further reduction of the product of coarse breakers—a product from 3 in. to 6 in. in size—the common practice has been to use smaller jaw or gyratory crushers or large rolls. The tendency toward simplification is well illustrated in the late type of Symons disk crusher, which is particularly suited to this work of secondary crushing. Its freedom from heavy vibration, few and long-lived wearing parts, true crushing action, uniformity of product which contains very little oversize, and low first cost are bringing this machine into wide favor with mill men.

The crushing members are two dish-shaped disks of manganese steel placed with their hollow sides facing each other. These disks rotate in the same direction and at the same speed. They are supported at an angle to each other, so that there is a wider opening between the edges of the disks at one part of their circumference than at the opposite part. The material to be crushed is fed into the space between the disks through a central feed opening in one of them. Centrifugal force then throws the material into the space where the disks are widest apart, and on being carried around it is crushed as the disks come closer together. The action is a true crushing one and not a combination of crushing and grinding. Particles sufficiently fine are thrown out between the disks, while the larger particles are again subjected to crushing. The disks can be adjusted to compensate for the wear, and thus a uniform product can be maintained.

Sizes and capacities of these disk crushers are given in Table I.

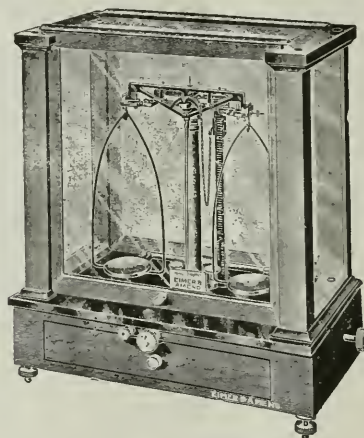
Cost for repairs and renewals ranges from 0.2 cent to 0.6 cent per ton of ore crushed. In one case a set of disks crushed 130,000 tons of hard rock and gravel from 6 in. to 1 in. In another case, crushing ore, the record for two different sets of disks was 155,385 and 200,812 tons, at costs of \$0.0014 and \$0.00109 per ton, respec-

Size of crusher...	18 in.	24 in.	36 in.	48 in.
Size feed opening	1.5 in.	2.5 in.	3.5 in.	6.4 in.
Minimum exit opening and tons per hour for best results	5-8	1/2" 12-15	3/4" 25-30	1" 45-60
Minimum capacity, tons per hour, when crushing to size given	1/2" 8-10 3/4" 10-12 1" 12-15	1/2" 18-20 3/4" 20-25 1 1/2" 25-30	1" 30-45 1 1/2" 45-60 2" 50-60	1 1/2" 60-80 2" 80-100 2 1/2" 100-120
Horsepower required	12-18	18-25	30-40	50-65

tively, for disks. These records were made on 48-in. crushers, handling 45 tons per hour, crushing from 3 in. to 7/8 in. and requiring 35 hp. each. The total cost of operation for a period of eleven months was \$0.01598 per ton crushed, including an extraordinary cost of \$0.00228 per ton due to steel getting into the crusher, leaving a normal cost of \$0.0137 per ton crushed.

Chain Vernier Analytical Balance

The recently developed Christian Becker chain balance which is featured by its extreme simplicity, is shown in the accompanying illustration. The balance has a chain fastened at one end to the right side of the moving beam of the balance and at the other end to a slide arranged with a vernier. As this slide is raised or lowered



CHAIN BALANCE

the pull on the beam is increased or decreased, thus creating a series of different weights read from a scale on which the slide moves.

The chain is of gold and the slide is operated by a thumb screw from the outside of the balance so that weighing can be done with the window closed. The saving in time effected by simply reading the vernier and the doing away of small weight transferring are also important factors. Troublesome riders and small weights up to 50 mg. are eliminated.

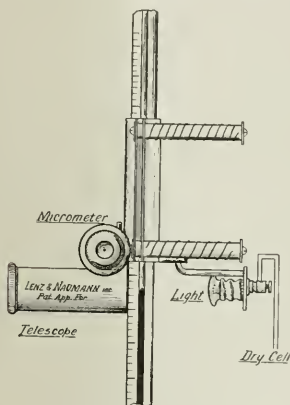
The balances are sensitive to 1/20 mg. They are sold by Eimer & Amend, New York City.

The Manufacture and Uses of Alloy Steels is the title of Bulletin No. 100, United States Bureau of Mines, a timely publication on the properties and methods of manufacture of materials that are coming into wide metallurgical use. The chemical composition and physical properties of different alloy steels are given, both for those that find extensive use and others that are less well known at the present time.

Micrometer Reading Device

A reading device for thermometers and burettes which comprises a mechanically adjusted micrometer reading feature in addition to the magnifying lenses is shown in the accompanying illustration. The optical equipment consists of a combination of lenses, and in addition there is an adjustable lens with a very fine hair line through its center and connected to a graduated micrometer screw in such a way that it may be moved across a certain space in either direction. This makes it possible to subdivide the space between any two graduations of a thermometer, burette, etc., in from two to twenty parts. A small electric-light bulb which comes in back of the thermometer, burette, etc., facilitates the readings. The device is very light, being made of aluminum throughout.

In order to compensate for the error due to parallax a line is made on the small electric-light bulb so that three lines are available, the one on the lens, the line to be read on the thermometer, and the line on the bulb.



MICROMETER READING DEVICE

If the lens is adjusted until these three coincide each time no errors will occur.

To give an example of using this device, say the mercury of a thermometer graduated in degrees registers somewhere between 97 and 98 deg. C. The scale on the head of the micrometer screw is turned to zero, the movable lens with its dividing line set parallel to the graduation mark at 98. By turning the head of the micrometer screw, the dividing line will move from 98 deg. to the next graduation at 97 deg. As soon as it is parallel with 97 deg., we stop turning the scale, which may now read 12. Now we turn back the micrometer screw till the dividing line is parallel with the mercury thread, which is somewhere between 97 and 98 deg. We read off once more the scale of the micrometer screw, which, say, is 8. As the total distance of the mercury from 97 was 12 minus 8, which equals 4, then the exact point of the mercury in the thermometer was $97 \frac{4}{12}$ or $97 \frac{1}{3}$, not $97 \frac{1}{2}$, as it would have appeared with an ordinary reading device.

This device is known as the Lenzman Micrometer Reading Device and is sold by the firm of Lenz & Nudmann, Inc., Pullman Building, New York.

The Standard Calorimeter Company, East Moline, Ill., has issued catalog B, describing the Parr coal calorimeter, gas calorimeters, sulphur photometer and total carbon apparatus.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Aqueous Bath Apparatus

(Continued)

568,258, Sept. 22, 1896, Victor Joseph Kuess, of Bordeaux, France.

Relates to a process of and apparatus for distilling fatty substances, and consists of a steam-jacketed retort, the exhaust steam from which passes through the condenser to aid in drawing out the vapors from the retort. The retort is further internally heated, and the contents thereof treated with steam from a manifold having a plurality of perforations, steam issuing therefrom passing through the material to be distilled. The retort is also supplied with an electric resistance heating coil for internal heating, and also with a pair of parallel horizontal electrodes, preferably of aluminum, by which the ascending steam and fatty vapors may be subjected to electrolysis.

573,355, Dec. 15, 1896, Marshall Pridham, of Philadelphia, Pa., assignor, by direct and mesne assignments, to the Electric Rectifying and Refining Company of Camden, N. J.

Relates to apparatus for purifying and decolorizing saccharine liquids, water, etc., from nitrogenous, organic, or mechanical impurities, and consists of a preferably long rectangular tank containing electrodes; the tank is filled with the liquid to be purified by an injector which also thoroughly mixes the liquid with ozone. The liquid is electrolyzed by passing a current from an aluminum or zinc anode supporting a quantity of active material, such as aluminum hydrate, or zinc oxide, the active material passing to a negative electrode. Before electrolysis, the tank is exhausted of air or other gases, which removes entrained gases from the liquor. During electrolysis, a stream of ozone is injected, the ozone oxidizing the impurities, which settle to the bottom and may be drawn off. The aluminum hydrate also collects impurities under the action of the current, and settles either on the cathode, or at the bottom of the tank. If the liquor is not sufficiently purified, it is then sprayed into a cylinder containing air under pressure, the sprayed liquid being treated with ozone while entering the cylinder, and the liquid being treated with ozone by a perforated manifold, one section of which rotates in the cylinder. The liquid may then be subjected to a secondary treatment, by first exhausting the air, then admitting ozone through the manifold.

574,038, Dec. 29, 1896, Richard J. Marks, of Hartford, Conn., assignor of one-half to William P. O'Toole, of same place.

Relates to a work-holder for articles to be electroplated, the holder consisting of a pair of hinged wood frames, the top and bottom of which are covered with wire netting. The bottom covering is divided into four insulated sections, separated by wood cleats, the sections are connected to the negative wire from alternate ends, so as to provide a more uniform distribution of current to the articles to be plated.

591,730, Oct. 12, 1897, Willy Bein, of Berlin, Germany.

Relates to a process of and apparatus for electrolyzing solutions. The apparatus consists of a cell divided by impervious vertical partitions into two, three, or four compartments, the partitions not completely

separating the compartments from each other, but leaving a continuous liquid connection between them. With the four compartment cell, the two outer partitions extend downward from the top about three-fourths the distance of the cell, the intermediate partition extending upward a like distance. Above the intermediate partition, a depending adjustable gate is provided to vary the area of the liquid connection or passage. The outer compartments are covered, and in the electrolyte are placed horizontal electrodes near the surface thereof. Gaseous products pass off through vents, while products heavier than the electrolyte, such as sodium hydroxide, sink, and may be drawn off periodically. The electrolyte forms a fluid diaphragm between the anode and cathode, and is placed in the inner compartments; it is replenished as often as necessary. A modification consists in supplying a slow stream of electrolyte to the anode compartment, and allowing slow streams of anolyte and catholyte to siphon off from the electrodes. The patent should be consulted for details.

605,835, June 21, 1898, Emile Andreoli and Gabriel Andreoli, of London, England.

Relates to the electrolytic production of amalgams, and describes a horizontal cell consisting of two outer anode compartments, and a central cathode compartment, separated by porous partitions, the floor of which is covered with mercury. In the outer compartments are solutions of salt, and a layer of water covers the mercury to the height of the salt solutions. When the mercury is sufficiently rich in sodium, it may be withdrawn, and used for amalgamated copper plates to be used in the recovery of gold, etc., by amalgamation in gold mining. The central compartment may contain a mass of inert material, such as a block of cement, to provide a narrow channel for mercury next to the porous diaphragm, and thereby economize in mercury.

621,907, March 28, 1899, Herbert H. Dow, of Midland, Mich.

Relates to an electrolytic cell in which a layer of solution similar to the electrolyte surrounds a closed cell, thereby preventing any leaks of gas, etc.; or the layer of liquid may only cover the top of the cell. The liquid above the cell also filters into the pores of the carbon electrodes which project through the top of the cell, and into the cell, thereby preventing creeping of salts, etc., through the carbons.

625,489, May 23, 1899, William Y. Buck, of Bristol, Conn.

Relates to a work holder for electroplating, and consists of a metallic bar having alternate equally and oppositely inclined holes for the reception of articles to be plated, such as unmounted table knives. The tangs are inserted in the holes, the blades projecting upward and outward at an angle of approximately 50 deg. apart. The bar is suitably suspended in the electrolyte. During deposition, the more concentrated layers of electrolyte are at the bottom of the tank, and ordinarily this would result in a heavy deposit upon the tangs of the knives; in practice, however, the tangs exert a shadowing action upon each other, resulting in a relatively weak deposit. Since the blades are widely separated, they do not exert a shadowing action upon each other, and receive a normal deposit.

637,313, Nov. 21, 1899, S. Wicks, of Cleveland, Ohio.

Relates to an apparatus for sharpening files, and consists of a lead-lined tank containing a suitable acid electrolyte. The tank contains a plurality of vertical pockets in its walls, having open tops and bottoms, and perforated shields therefore, to prevent accidental contact of the cathodes within said pockets, and the files, which are connected as anodes. The files are separately electrically connected to the anode wire by a switch, and

are adjustably suspended vertically in the electrolyte.

645,785, March 20, 1900, W. Y. Buck, Bristol, Conn.

Relates to holders for electroplating spoons, etc., and consists of a pair of wires, twisted together at intervals, and leaving a plurality of rectangular loops between the twisted sections. The twisted wires are now bent in the shape of a rectangle, having a length several times its width, and provided with a handle or bail by which it is to be suspended in the electrolyte and electrically connected to the negative wire. The spoons to be plated are inserted in the loops, with the inner sides of the bowls facing toward the center of the frame. With this arrangement, the bowls receive a heavy plating on the outside, and a thinner deposit on the inside.

645,786, March 20, 1900, W. Y. Buck, Bristol, Conn.

Relates to the art of electroplating, and covers the process of "shadowing" surfaces of articles to be electroplated, thereby effecting a thin deposit on the shadowed surfaces, while producing a thick deposit upon the exposed portions. This patent is for the process used with the holder described in patent No. 645,785.

647,960, April 24, 1900, George Weltten Gesner, of New York, N. Y., assignor to Harleston Corbett Gesner.

Relates to an electrolytic cell comprising a vessel and an anode and cathode of an alloy of iron and hydrogen, the hydrogen being present in such quantity as to prevent all oxidizing action, including that arising from chlorine. The patent refers to several other patents and applications covering the alloy and processes for its manufacture. Several methods are briefly referred to in this patent, one of which is to force hydrogen through the molten metal, and then to remove the alloy that has been formed from the unalloyed iron either by puddling and squeezing, or by grinding and sifting. The alloy may contain hydrogen in the proportion of eleven one-hundredths of 1 per cent and upward. A cell comprising an anode and a cathode of this alloy is adapted for the decomposition of saline solutions, and salts which contain an excess of chlorine. The alloy is said to be capable of resisting oxidation and corrosion from heat or chemical action arising from either atmospheric or more powerful influences.

649,614, May 15, 1900, Antoine Edouard Peyrusson, of Limoges, France.

Relates to an electrolytic cell for the decomposition of electrolytes, and consists of concentric electrodes, the inner one contained in a porous cup which is provided with a faucet at the bottom, the outer one surrounding the porous cup and contained in an outer cell also provided with a faucet at the bottom. Both electrodes are in the form of a helix, and both fit tightly against the walls of the porous cup, and the cell. Fluids to be electrolyzed are admitted from faucets above, and travel in helical paths between the convolutions of the helical electrodes, the spaces between the convolutions constituting electrolyte compartments of considerable length. The velocity of flow of electrolyte may be controlled by the faucets at the bottoms of the inner and outer cells.

675,662, June 4, 1901, Samuel Lowe, of Waterbury, Conn.

Relates to a rack to support articles to be electroplated, and consists of a central vertical rod provided with a hook at the upper end, and a plurality of horizontal arms secured thereto, and extending each side thereof, and upon which the articles to be plated are placed. The upper horizontal arm has its ends bent upwards, while the lower arm has its ends bent downwards. In order to prevent the articles to be plated from slipping off the arms, end-pieces are provided having openings to receive the extremities of the arms, the upper and lower arms being sprung into place, their bent ends securely holding the end-pieces.

Industrial Notes

The Hooker Electrochemical Company's new plant at Niagara Falls is now in rapid course of erection by the Samuel Austin & Son Company. Probably 700 men are on the job now; at night, from 150 to 200. The entire work is being handled on a "cost-plus" basis. There is an engineering force of over sixteen men on the job, in charge of Mr. H. F. Jacobi. There is also a complete accounting force under an auditor, so that Mr. Hooker has on his desk each day at 9 a. m. cost reports covering each unit of work for the previous day.

C. W. Leavitt & Co., New York, have been appointed exclusive American selling agents for the Carlton Iron Company, English manufacturers of ferromanganese.

A dyestuff plant will be erected by Messrs. Marden, Orth & Hastings on a plot of land comprising ten acres in the meadows near Jersey City.

The Oliver Quartz Co. has taken over the business of T. C. Oliver, Charlotte, N. C. The quartz sold by this company has been used in packing a great many of the acid towers in eastern chemical plants.

The Pacific Coast Steel Company recently closed contracts for extensive enlargements to its plant to provide for the manufacture of structural steel on a large scale.

Bavarian Porcelain.—Messrs. Lenz & Naumann, Inc., New York, announce that they still have a good stock on hand of imported Bauscher Bavarian porcelain which is said to equal the Royal Berlin in acid, alkali and heat-resisting qualities.

The American Steam Pump Co., Battle Creek, Mich., has recently received an order for all the pumps to be installed in the new Curtis Bay distillery of the Republic Distilling Co., Baltimore. The order includes pumps for fusel oil, alcohol, gasoline, fresh and salt water, etc.

The Peruvian Potash and Chemical Co., Philadelphia, Pa., recently incorporated, intend to develop potash deposits in Peru. These deposits are stated to have lain for centuries untouched, with only a 3-ft. overburden of soft sand and gravel. The deposits lie on the southern boundary line of Peru, and are ten miles inland from the sea. Shipments to the United States are contemplated about April 1.

The National Ox-Hydric Company of Chicago, Ill., will install commercial oxygen plants for the sale of oxygen and hydrogen in Chicago, Pittsburgh, New York, Boston, Minneapolis, St. Louis, Kansas City, Detroit, Philadelphia and Los Angeles. Machinery and equipment for these plants is all completed and considerable of it has been shipped. The company will use its own generating system.

Japanese Electrochemical Works.—The British vice-consul at Osaka reports that a company has been formed in Osaka with a capital of 350,000 yen (about \$178,500 at par) for the manufacture of caustic soda and bleach by the electrolysis of common salt. A factory is to be erected at Kyushu where hydroelectric power is fairly cheap. The machinery is to be Japanese. A monthly output of 300,000 lb. of caustic soda is spoken of.

The Snyder Electric Furnace Co. of Chicago, Ill., announces sales of electric steel furnaces during 1915 from their English office at Bradford, Yorkshire, England, to the following companies: The Daimler Co., Ltd., England; Thwaites Bros., England; Summerson & Sons, Ltd., England; National Steel Foundry Co., Ltd., Scotland. In addition, four large furnaces for special smelting work have been contracted for as well as a small furnace for carrying on initial experimental smelting work.

Magnetic Separator Pulley.—A recent circular of the Cutler-Hammer Clutch Co. of Milwaukee describes its magnetic separator pulley for use in paper and pulp mills, cement plants, gypsum plants, starch mills, foundries, steel plants, mines, glass factories, rubber plants and other industries. This magnetic pulley is designed to remove stray pieces of iron and steel and is of particular value where crushing or pulverizing machinery is used, as by removing the nuts, bolts, pick-heads, etc., it prevents injury to the crusher blades. In other industries it is used to remove small particles that detract from the purity or quality of the product. An example of the latter is the sugar refinery.

Chalmers & Williams, Inc., of Chicago Heights, Ill., have received an order from the New Cornelia Copper Co. at Ajo, Ariz., for twelve 48-in. Symons fine reduction disc crushers, which will be used in their plant to reduce 4000 tons from 4 in. to $\frac{1}{4}$ in. Orders were also recently received for similar machines from the Chile Exploration Co., Hollinger Gold Mines Co., and C. S. Christensen, Kristiania, Norway.

The Apollo Electric Steel Co. has been organized for the manufacture of electric furnace steel at Apollo, Pa. A site of 8½ acres has been secured and the contract let for suitable steel buildings. They will be of the most modern construction and will be equipped with every facility for the manufacture of high-grade steel. Two Snyder electric furnaces will be used, each having a capacity of 100 tons per day. The management of the company will be in the hands of the following men: Robert Lock, president, formerly with Allegheny Steel Co. and American Sheet & Tin Plate Co.; J. Arthur White, metallurgical engineer, formerly with American Sheet & Tin Plate Co.; W. E. Troutman, manager of Vandegrift plant of United Engineering & Foundry Co.; J. E. Gallagher, of Apollo, and Carl H. Booth, vice-president of the Snyder Electric Furnace Co., Chicago.

Standard Tables for Petroleum Oils.—Samples of petroleum oil have been collected from different parts of the country by the United States Bureau of Standards, and the specific gravity determined over a wide range of temperature. From the data obtained tables have been prepared for determining the true specific gravity and volume of oil at the standard temperature, when these quantities are measured at other temperatures. Tables have also been prepared for showing the relation between specific gravity, Baumé degrees, and pounds per gallon. The new tables will be especially useful in determining the quantity of oil in large shipments. Circular No. 57 of the Bureau of Standards presents the results of these experiments, and it may be obtained by interested persons from that Bureau.

Measuring Barium Compounds in Rubber Goods.—By means of tests made on compounds of known composition, prepared at the U. S. Bureau of Standards, a method has been devised which permits the quantitative determination of barium carbonate in the presence of either lead sulphate or barium sulphate, the two sulphates most commonly used in rubber goods. This is of help in determining the total sulphur when both barium carbonate and sulphate are used as fillers. These tests are described in Technologic paper No. 64, which may be obtained from the Bureau of Standards.

The Riche Adiabatic Calorimeter, sold by Messrs. Lenz & Naumann, Inc., of New York, and described in this journal September, 1914, page 606, is reported to find increasing application where accurate results are required, on account of the many interesting features which make it an accurate measuring instrument.

Personal

Mr. A. A. Cole is the nominee for president of the Canadian Mining Institute. He has been known for his work as mining engineer for the Temiskaming & Northern Ontario railroad, with particular reference to the mining and metallurgy of the Cobalt and Porcupine districts.

Mr. Herbert Coward, who for three years has been in charge of the Spiro Turbine Department of the Buffalo Forge Co., and for four years previous engaged in sales and engineering work in connection with air conditioning apparatus, has been appointed steam engineer of the Carrier Engineering Corporation and is now located at its main offices, 39 Cortlandt Street, New York.

Mr. A. M. Douglass, formerly chemist in charge of the laboratories of the Merrimac Chemical and the New England Manufacturing companies of Boston, Mass., is now engaged in the installation of the plant and process of the American Bromine Company, located at Midland, Mich.

Mr. W. B. Easton, chief engineer for Chalmers & Williams, is visiting Arizona mills in the interest of his company.

Mr. Justin H. Haynes and Mr. Edmund Leet, who have been in the Cripple Creek district for the past five months, have completed their experimental work on flotation for the Vindicator Consolidated Gold Mining Co.

Mr. Henry Howard, vice-president of the Merrimac Chemical Co., delivered an address on the "Necessity for an American Dyestuffs Industry to Aid Export Trade in Textiles" at the National Foreign Trade Convention at New Orleans on Jan. 27-29.

Mr. H. C. Humphrey, chief chemist of the Eastern Branch of the Corn Products Refining Company in New York, died of pneumonia after a short illness.

Mr. S. A. Ionides has returned to Denver from a professional trip through the Northwest.

Mr. B. T. Klein has been appointed Pacific district manager of the Bristol Company. This is a new branch office recently established at 727 Rialto Building, San Francisco. Mr. Klein was Chicago manager for the company for six years and had charge of the company's exhibit at the Panama Exposition.

Mr. E. W. Lawler has again become associated with the Hardinge Conical Mill Co. and is located at the New York office. New quarters have been leased by the company at 120 Broadway in the Equitable Building, and it is expected that they will be at the new address by Feb. 20.

Mr. H. S. Mulliken is manager for the mines and smelter of the Penoles company at Mapimi, Durango, Mexico.

Dr. Charles S. Palmer, formerly professor of chemistry at the University of Colorado and later president of the Colorado School of Mines, has accepted a fellowship in the Mellon Institute for Industrial Research at Pittsburgh.

Mr. W. J. Pentland, general manager for the Amajac Mines Co., Hostotipaquillo, Jalisco, Mexico, is still at Guadalupe. In the last communication received from him, dated Dec. 28, 1915, he states that it has been impossible to carry on any work at the mines.

Mr. Charles F. Rand was elected president of the United Engineering Society at the annual meeting, Jan. 27, Mr. Gano Dunn declining re-election.

Dr. L. D. Ricketts has gone to South America to inspect recent developments in copper mining and metallurgy.

Mr. Frank W. Steere, vice-president of the Steere Engineering Co., Detroit, Mich., was awarded the "Beal Gold Medal" for the best paper read at the annual

meeting in 1914 of the American Gas Institute. Mr. Steere's paper was entitled "An Electrical Process for Detarring Gas," and was published in our issue of December, 1914, Vol. XII, page 775.

Mr. W. G. Swart has transferred his office from Denver to Duluth, Minn., where he is engaged on investigations relating to the treatment of iron ores.

Mr. S. W. Traylor, president of the Traylor Engineering & Mfg. Co. of Allentown, Pa., has been chosen manager of the ordnance department of the Crucible Steel Company's plant at Harrison, N. J. The new position will not interfere with his old one.

Mr. Thomas F. Williams, formerly chief mechanical engineer of the Aeromarine Plane & Motor Co., of Avondale, N. J., and a specialist in carburization of fuels, has accepted the position of chief consultant of the Board of Engineering Research, Mechanical Applications, of the Powdered Coal Engineering & Equipment Company of Chicago and will direct the research work of that company in the carburization of comminuted fuel and the application of automatic mechanical regulation and controls thereof.

Mr. Louis A. Wright has severed his connection with the General Development Co. and has joined the staff of the American Metal Co. He has sailed for Chile, which will be the scene of his activities for the next two years.

Book Reviews

Inventions and Patents. By Philip E. Edelman. 288 pages. Price \$1.50, New York: D. Van Nostrand Company.

This book is intended to be a practical guide to the inexperienced inventor who has not had the opportunity to know of the numerous obstructions in the way of applying for and securing U. S. patents. The author devotes a few pages to the development of the patent system and then in considerable detail describes the methods to pursue in choosing an attorney, making applications, patent office practice, methods of protection, sale of patents and so on. An appendix gives a digest of important patent decisions and the various forms used in patent procedure and closes with a short bibliography of the general subject.

The author has carried out his intentions in a successful manner, his style is easy, the language simple and non-technical. The book is well printed in good type and deserves a place on the shelves of every manufacturer.

Autogenous Welding and Cutting. By Theodore Kautny, translated from the German by the author and James F. Whiteford. 157 pages. Price \$1.00, New York: McGraw-Hill Book Company, Inc.

This handbook of the art of welding is a recent résumé of the latest practice in Germany and is intended to go directly into the hands of the operator in the works. It describes the methods of obtaining the various gases used, their purification, containers, pressure, regulation, piping and fittings. The author then devotes some pages to a description of blowpipes of various kinds and exactly describes their methods of use. Various kinds of metal are then taken up and the user is told just how to make vessels and articles of any shape. Copious illustrations assist the unusually clear description of operations and it is hard to see how a workman with average intelligence can fail to improve his technique by an occasional reference to this book.

The author is to be congratulated on laying before the public in so practical a way what has been too often considered in the light of trade secrets. No one who contemplates adding a welding department to his equipment should proceed before he has well studied this book.

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The Power Famine at Niagara Falls and National Industrial Preparedness

Elsewhere in this issue (on pages 239 and 259 respectively) full reports will be found of two unusually interesting meetings held last month by the two liveliest and most aggressive local sections of the American Electrochemical Society, the Niagara Falls section and the New York section. At Niagara, under the chairmanship of Mr. F. A. Lidbury, the subject of discussion was the power famine at Niagara which has been growing worse from year to year and is now most serious in its threatening consequences. At New York City, under the chairmanship of Dr. C. G. Fink, the discussion related to "electrochemical war supplies" with special reference to national preparedness. Strange it may seem but it is true that the subjects of the two meetings are intimately related to each other. The discussions at both meetings deserve the most careful attention of everyone. We can touch at this place only on a few salient points of many which were brought out.

The fundamental trouble with waterpower legislation in this country in the past has been that those responsible for it have been too exclusively obsessed with one-sided aesthetic scruples and with the fear of the ghost of a waterpower trust and have never risen to a full realization of what developed waterpower means or would mean to the consumer and to the whole life of the nation. It is not generally and not clearly enough realized that the price this country is paying continually for the preservation of the spectacle of Niagara Falls amounts to something like a million tons of coal a week. Using another unit for expressing the economic equivalence, Mr. F. J. Tone brings the matter even more strikingly home to the public: if the Niagara power was devoted to the production of nitrogen fertilizer it would produce sufficient nitrogen for 3,000,000 bushels of wheat a day. Let it be clearly understood that the failure to develop available waterpowers means a continuous irretrievable economic loss of startling dimensions. The only real loser is the nation.

Mr. Tone's nitrate example is particularly appropriate because for the industrial self-containedness and for the very independence of a nation a sufficient nitrate supply is a fundamental prerequisite in peace and in war, for fertilizers and for explosives. The fact is that in the past this country has relied wholly on nitrate importations from Chile. Mr. W. S. Landis is right in pointing out that Germany has been able in a single year to make itself independent of importations by rapidly developing electrochemical nitrate processes on a marvelous scale, and he is also right in saying that with respect to the production of cyanamid and subsequent transformation into ammonia and nitric acid "there are

no problems the solution of which is not now resident in the United States, and therefore we feel that this country is to-day in as good, if not in a better position to supply its own nitric acid for ammunition purposes than Germany was at the beginning of the war." But to state the facts in the case completely, it must be added that the only large American cyanamid plant is not in the United States, but on the Canadian side of Niagara, and that the cyanamid industry is one of those which were forced by the power famine on the United States side to go out of the country. When it comes to figure the cost of undeveloped power and the economic loss of the country, let the expatriation of industries of fundamental importance be not forgotten.

We cannot expect too much from our law makers, but we expect that something be done. Mr. Albert H. Hooker's proposal is excellent. Well over 1,000,000 hp. more could now be developed at Niagara and not a bit of injury would be done to the scenic grandeur of the cataract if a little engineering skill were used in placing the proper brakes and deflectors. Let this be done with the provision that for every 100,000 hp. newly developed, say, 10,000 hp. be devoted to the fixation of atmospheric nitrogen; the more varied the methods the better. In any sensible program of preparedness chemical preparedness and chemical self-containedness must be fundamental and nitrate production from the air must play a big part; the crux of the matter is more Niagara power. The American electrochemists may be safely relied upon to do the rest.

Metal Prices and Wages

The wage earner in the mining and metallurgical industries is sharing with the operator in the profits flowing from the increased prices of the base metals. The daily press cites numerous instances of wage increase and of sliding wage scales based on metal prices, particularly in the copper, zinc and steel industries. Lead has not yet shared in the general advance in as great measure as the other metals.

Utah mining and smelting companies generally have granted advances, the Utah Copper Co. alone being reported to have increased its pay-roll by about \$50,000 per month. Kansas and Oklahoma zinc smelters and Joplin mining companies also have granted substantial increases. Colorado and Eastern iron and steel workers have been recognized, and wherever unusual profits are being made the worker is sharing in some degree. Conditions are in marked contrast with those of August, 1914, when production was curtailed and workmen were offered employment on half time.

The attitude of the operators is wise as well as just. The workman is entitled to a share in the enhanced value of his product. This is no time to incur his enmity or ill will, for he is a factor that cannot be ignored. We like to believe that the operators recognize the justice of these wage increases, and that they are not merely placating the men through fear of dissension or strikes that would mean cessation of operations and consequent loss. And signs are not lacking that an intelligent view of coöperation is surely re-

placing the sentiment of antagonism that prevailed all too widely in the ranks of employer and employee only a few years ago. The millennium is not yet at hand, but we are in a fair way to avoid repetitions of the distressing state of affairs that recently prevailed in Arizona for four months, and which has been settled on an amicable basis. A point to be kept in mind by both sides is the necessity of being equally considerate and tolerant when prosperity is not as marked as it is to-day.

A Most Remarkable Steel Situation

If the situation now obtaining in the steel market had been portrayed a year ago the sketch would have been considered fantastically fanciful. The reality is difficult to grasp. It seems impossible. The future of a market is a resolution of the forces, but in this instance no resolution seems reasonable; it looks as though it would have to be in the fourth dimension!

The steel industry, the industry of making soft steel by the Bessemer or open-hearth process, is not very old. The art passed its semi-centennial several years ago, but it was not until about a quarter century ago that the manufacture of puddled iron in the United States ceased to increase. Thus the history of the steel market is not so long but that it can be scrutinized for possible parallels. None can be found. Soft steel became the dominant wrought ferrous product during a period of industrial depression, and at its close there was a "boom," prices skyrocketing in the latter half of 1899, but the boom was short lived, and the total turnover at high prices was small from a tonnage standpoint. The next upward movement, culminating in 1902, found finished steel products under such control, a control that proved quite temporary, that they advanced unduly with respect to material in its cruder stages. Since 1902 the steel market has attained three high points, in 1907, 1909 and 1912. Of these the highest was that of 1907. At the end of 1915 the average price of finished steel products was level with the high point of 1907, \$4 a ton above the high point of 1909 and \$6 a ton above the high point of 1912.

It seems to be a fair statement, therefore, that at the end of 1915 the steel market was on the verge of passing beyond bounds. The period 1905-6-7 represented the greatest period of sustained and heavy demand in the history of the steel industry, and to produce higher prices than then reached would certainly require altogether exceptional and extraordinary conditions. Since the first of this year the steel market has advanced an average of fully \$7 a ton, being by that length virtually out of bounds, and the going is still strong. The curve of prices is concave to the blue sky. In bars, plates and shapes, for instance, the nine advances that occurred in the first ten months of 1915 were of \$1 a ton each. Then came advances of \$2 a ton each, and the latest advance, made about Feb. 18, was \$5 a ton. It would be instructive if the formula for the graph could be written, dx being first of the order of \$1, then of the order of \$2 and then of the order of \$5.

The manner of doing business in steel is likewise

without precedent. Hitherto as prices advanced the steel mills would cover their customers farther and farther ahead, so that the advance in prices realized upon shipments would be quite gradual, and buyers would be well protected for the future. In this movement the mills began to curtail the making of contracts after prices had reached a moderate level, and of late they have been disposed to accept little but specific orders. The following of such a policy has tempted buyers to make up dummy specifications, which parade as specific orders, buyers knowing that the mill cannot ship for months and that opportunity will therefore be afforded to change the specification when the real wants are clearly seen. Thus the tonnage of so-called "specifications" on mill books is not as close an index as usual to what the mills will actually be called upon to deliver.

From the viewpoint from which the steel market has been regarded in the past the present situation would be impossible, and the future likewise impossible. One usually judges the future in human affairs by mapping out the possible courses of events and selecting the most probable, as the railway engineer selects the most feasible course for his proposed road. When he finds no possible course, however, he loses his job. There is no reasonable course for the steel market now to follow. Prices are already above the traditionally "safe" level, yet show a greater advancing tendency than ever. That might be held to suggest a break in the market in the near future, but a break seems to be as improbable as anything.

It is a question, however, whether there has been any really conclusive test in the past as to the ability or willingness of steel buyers to pay one price or another. To an extent the matter has hinged upon what the buyers have been able to obtain for their product, for it is rarely indeed that the ultimate consumer buys steel from a mill. As a rule steel markets have been made or broken not by the ability of the buyer to pay, but by what he expected of the future, whether prices were likely to advance or decline. His ability has not been seriously tested.

In any event, however, the "buyer of steel" is not a homogeneous quantity. One buys steel to make watch springs, another to build a bridge. There are all gradations. With sufficient detailed knowledge the buyers could be classified, the aggregation analyzed, and the groups arranged in the order in which high prices would curtail the expression, in actual orders, of their requirements or desires. If the desire to have steel represents neither more nor less than the quantity of steel that can be produced, and price exercises no deterrent influence, the production will be bought. If the desire exceeds the supply, the price can be a deterrent, as to various classes of steel, to the extent of this excess, and still leave purchases equal to the possible supply. If at any moment the deterrent is less than this excess, relief is found in price advances.

The extent to which high prices may be a deterrent to steel purchases may be overrated if the average experience of the past be taken as a guide, for the propor-

tions in which steel has been bought of late are quite different from the proportions of the past. There has been a much smaller proportion of structural material and a much larger proportion of steel for automobiles and most other classes of material. If all the steel now being shipped could be followed to its ultimate destination, where it is to perform its actual service, the value in the case of a great percentage would be found to be a large multiple of the price received by the mill, whether that price were a cent and a half a pound or three cents a pound. In ordinary times it does not follow that the price would not be an important consideration, the buyer perhaps concluding at times it would be better to wait. The times now, however, are so disorganized that the buyer has no idea what is coming. Some buyers would not buy now even at low prices; others may care nothing for price.

If little is known as to the prospective willingness of domestic buyers to pay high prices for a large tonnage of steel—for at present the high prices are being paid for but a small tonnage of the steel shipped, owing to the filling of old orders—still less is known as to the export demand. It is currently observed that prices bid for export steel are higher than the regular prices asked in the domestic market, but the mills have been so busy arranging their orders that they have negotiated on little of the export inquiry. In good times prior to the war the great iron and steel exporting countries, Germany, England, Belgium, France and the United States, have furnished about 10,000,000 tons a year to the non-producing countries. At the present time such exports are at a rate probably somewhat under 4,000,000 tons, a trifle more than one-half being furnished by England. Obviously there is room for a large increase in our export trade, as England can scarcely increase her exports, provided the price will be paid. Imagine a conical shaped vessel containing water, with an outlet at the bottom. How much water must escape to reduce the pressure one-half? No answer. Is the cone upright or inverted? Thus with the pressure for steel for export, which causes high bid prices. One does not know how much tonnage would be sold before the bid prices would be greatly reduced.

In all this confusion one thing seems reasonably certain. When the turn comes, whether it be relatively near at hand or far distant, steel prices will not drop with the dull disheartening apathy that has characterized such declines in the past. Wants that were not expressed when prices were higher will be found expressed in orders as values decline; the buying cannot come to a sudden standstill.

The common view in the steel trade has been that the heavy demand for steel will last during the war, and even the sharper advances in prices now occurring have not served to convince the majority that the break in steel prices is likely to come sooner. The observation, of course, presupposes that the war will not be continued until complete exhaustion overtakes the belligerents, for in that case their purchases of American products would have ceased, and with it a part at least of our general industrial prosperity would end.

Readers' Views and Comments

The Chemist on the Board

To the Editor of Metallurgical & Chemical Engineering:

SIR:—Chemists are just like other men, and when they grow rich they are likely to become vain and cocky. Not all of them by any means; some are of such exquisite mental balance and are so wholesome of disposition that the more wealth and power they achieve the better it is for everybody all around. And yet very few of us are proof against the danger that accompanies the accession of wealth, or against the need of a camel ride, or against the vain belief that, so mounted, we can easily make the grand tour through the needle's eye without so much as losing any skin or compressing our camel. We know that others would have trouble and we even have concern lest they fail, but it is not so with us. We have just the balance, just the quality of poise, of *savoir faire*, of grace and general sensibleness to make it especially desirable that we be rich. This is our great illusion.

We say this because we believe it to be true, and more especially to take the sting out of what we are about to say. Observe, please, chemists are like other men and other men are like chemists. If they grow rich they are likely to suffer in character and in modesty. As soon as anybody has made his pile he may need to be treated with caution lest he flare up and lose his head and strut about and grow angry and demand more reverence and respect and admiration and obedience than his qualities warrant. The longer the credit balance the shorter the temper as a rule, and its operation can only be overcome by a well-oiled and easy-running condition of that part of a man's internal equipment that functions as generosity. By this we mean the larger generosity whereby one understands not only what another thinks but how he feels, and has the sympathy to avoid giving unnecessary pain. This quality is one wholly separate and apart from executive ability and good business sense.

Now if you want a competent board of directors to guide the affairs of an industrial undertaking, you must select men of experience and achievement in affairs and such men are likely to be rich. If they are, there is the danger that at least some of them may be crippled by rich man's vanity. You may sit on a board with such a man for years and not know he is suffering from this malady, and again, under some unexpected provocation it may crop out at any time in the form of a broad, yellow streak, to your amazement and distress.

In any concern engaged in the production of goods by means of chemical processes, there should be a chemist on the board for advice and to avoid mistakes. This for the same reason that there is a lawyer, either duly elected or present as general counsel, in like manner to avoid mistakes. It was intimated in the last issue of this journal that business men and especially bankers do not know chemists as such, and that few of them know the difference between a good one and a bad one, or how to tell them apart. The bad chemist has the advantage over the good one with men of business because he can promise so much more. There should be chemists on the boards of many corporations that are now even boastful that they haven't a single "theorist" in their whole establishment, if they are to avoid unnecessary waste and keep out of trouble. To hear some directors talk it would almost seem as though they would discharge a man if he owned a slide rule. It has

been so firmly insisted upon of late, however, that there is something in this chemistry, after all, that the style may be set some day to have "a chemist" on the board of directors of a manufacturing corporation. American business men, like some of their frailer sisters, are disposed to take "The Easiest Way"; and the easiest way in this connection would be to send down to the works and tell young Brown or Jones or Robinson who may be testing materials in their cupboard of a laboratory somewhere under the stairs, to come up to the office and sit in.

Then suppose the most affluent, the most pompous, the vainest if not the richest director, the father-in-law of the secretary of The Sand & Stone Co., were to offer the following motion: "Resolved, that, prices being equal, this corporation shall purchase its rock from The Sand & Stone Co." The young chemist apologizes for speaking and says that Sand & Stone are agents for Blue Mountain rock and that this rock seemed to show traces of Dubium which he fears might give trouble in the works.

"Whatcha mean?" roars the affluent one to the pale B. S.

"Well—I—er—it doesn't seem to me that it works as well as the Earth & Rock Co.'s product that I believe comes from Green Mountain. I thought I found traces of Dubium there, and, you know, there might be a catalytic effect—"

"Cataclysmic Effect!" exclaims the affluent one. "Young man, is that what you think or what you guess?"

"Why, I'm not sure but I think—"

"That's what you think, is it? Well, sir, when you know something let's hear from you, but we don't care for any of your guesses. The Sand & Stone Co. are the largest dealers in this material in the world and if I tell them to send us rock without any of this here Dubium in it, they'll send it. I call for my motion, Mr. Chairman."

The motion is put and carried.

In one year's time the asset of the corporation's name as a trademark becomes a liability; they cannot persuade people that their product is not tainted. Even after they have seen the folly of their ways and given up the use of Blue Mountain rock and turn out a product better than ever before, their reputation is still bad.

"Better not buy of 'em," says one customer to a prospective one. "They tried to run off a lot of inferior material on me, but I made 'em take it back."

"One of their drummers was in not long ago and he said they had had a fault but had corrected it; they had some Dubium in their rock they make it of, but he says it's all right now."

"That's what they say! Jever know a concern that wasn't all right when they wanted to make a sale?"

"That's so. Better be on the safe side," says Mr. Prospective Customer, and he buys from the rival company.

Now suppose instead of electing the young chemist from the works, a consulting chemist of standing is selected, retained and added to the board to avoid mistakes at the start, which is the Grand Economy. Let us imagine the same corporation, same chairman and president, same pompous old party with a son-in-law with Sand & Stone, same general counsel and the same other members except that Dr. Noyadont of the Noyadont Laboratories sits in the place of young Brown, the

chemist at the works. Unlike Brown, Dr. Noyadont has not bought himself a house in the neighborhood of the factory and has not married on the prospects of the good-will of the very board of which he is a member. Dr. Noyadont likes his annual retainer, which may be more than Brown's salary, but he does not live on it. Then let us imagine the same proposal of the affluent Mr. Fatwad that the corporation procure its rock from Sand & Stone.

Dr. Noyadont speaks up: "Sorry, Mr. Fatwad, but I shall have to oppose that motion. I've examined the Blue Mountain rock that they handle and it is not good for our purpose."

"Why not?"

"Appears to be Dubium in it."

"But these people are the largest producers of rock in the world and do you mean to tell me——?"

"I mean to tell you not to use any Blue Mountain rock. It's the best there is for some purposes, but not for us."

Old Fatwad observes that Dr. Noyadont is neither afraid nor uncertain of his ground. But he likes to have his way and he proposes a committee of three including Dr. Noyadont to ascertain—

"No occasion for me to look into it any more," says Dr. Noyadont. "Go ahead and buy all the Blue Mountain rock you want to," he continues, "but with it comes my resignation from the Board and from the office of your consulting chemist. Mr. Fatwad expects your processes to move on all calm and serene in the presence of a catalytic agent that may start up all sorts of reactions that you don't want. I can't be sure of your product under those conditions. If some member of the board were to propose to break the laws of the state or the nation, your General Counsel here would advise you against it, and if you were to persist in it he would resign. Well, here you propose to break Nature's laws and expect to keep out of trouble after you've done it. I call for the question, Mr. Chairman, because it involves a matter about which we should not be in doubt for one minute. And I offer my resignation now to take effect as soon as the motion is carried."

Mr. Fatwad then withdraws his motion. He may see a light and again he may not, but the chances are that he will, because he is nobody's fool. But rich-man's vanity is one of the most difficult things to overcome. When it is quiescent it is invisible and harmless; when it is active it is hard to endure and highly dangerous. The only way to deal with it when it is active is to whack it on the head. No employee can do this without providing for himself first, a good, safe runway into the tall timber.

There should be a chemist on the board of every corporation that has to do with chemical processes. He should be a man of attainment, of distinction and of backbone.

ELLWOOD HENDRICK.

New York City.

Engineers Interested in Preparedness.—The Monday night lectures given at the Engineering Societies Building, 29 West Thirty-ninth Street, New York, on military subjects under the direction of Maj. Gen. Leonard Wood are attracting large audiences. On the first Monday night, Feb. 14, more than 2300 engineers tried to attend. It was necessary to turn between 500 and 1000 away, even after holding an overflow meeting for 500 in a separate hall, where the same lecture was given as in the big auditorium but by another army engineer. The speaker in the large auditorium was Capt. Thomas M. Robins, who spoke on the duties of engineers in war, and what engineers in civil life will be called upon to do.

The Power Famine at Niagara

Meeting of Niagara Falls Section of American Electrochemical Society

(From Our Special Correspondent)

The Niagara Falls section of the American Electrochemical Society discussed the power situation at Niagara Falls at its February meeting, held at the Assembly Room of the Niagara Electric Service Corporation on the evening of February 2. A large and representative body of Niagara Falls electrochemists was present, and the proceedings were marked by a definiteness of purpose and intensity of interest of quite unusual order.

The chairman, F. A. Lidbury, opened the meeting with an explanation of the reasons for which it had been called. He pointed out that those present had long foreseen that the governmental restriction of power development at Niagara must ultimately result in the present situation, in which the shortage of power was seriously hampering the electrochemical industries and through them the industries of the country at large. Individual members had done what they could from time to time to point this out publicly, but there had been no concerted effort. It was time for this condition to cease and for members to stand together and to do whatever was possible to bring about such changes as would relieve the situation.

What the section could do was the main matter for discussion. He thought himself that its usefulness would be largely educational. Firstly, they had to educate themselves as to the situation. This was the main object of the meeting. Very few knew, for instance, how much power was generated on this side of the Niagara border, and how much imported from Canada; how much of the total amount was used for electrochemical purposes, how much for other. Secondly, they had to educate the local community; there ought to be a better realization of the dependence of the city's growth and prosperity on a continually increasing power development; thirdly, he pointed out the growing influence of technical societies and advised the education among their own and related societies of members as to the national importance of the matter; and, fourthly, they had to attempt to educate the people at large, who were fully awake to the significance of the dye situation, but quite ignorant of the far greater importance of the electrochemical industries, because the matter had not been properly brought to their attention. He asked F. L. Lovelace of the Niagara Falls Power Company and J. L. Harper of the Hydraulic Power Company to explain the present situation to the meeting.

F. L. Lovelace gave an interesting historical sketch of the power development at Niagara and of legislative acts restricting it. He contended that the limits set by the Burton Act, which limits were at present being insisted upon by the government in spite of the fact that the Burton Act had expired and the treaty with Canada allowed 4400 cu. ft. sec. more, were unfair to the Niagara Falls Power Company and that it had been the intention of the treaty convention in extending these limits to correct an error in the Burton law so as to permit the operation to full capacity of the plant of the Niagara Falls Power Company. He concluded with an analysis of the Kline bill now before Congress and showed that the result of this bill would be not only to make operation more difficult and restricted, but to place the whole of the present developments in jeopardy.

If Mr. Lovelace's address was, perhaps naturally, rather a piece of special pleading on behalf of the

Niagara Falls Power Company, that of J. L. Harper, who followed, dealt in an extremely witty manner with the situation from the point of view of the Hydraulic Power Company, Mr. Harper ironically thanking that company for their efforts to secure the extension of diversion limits from the 15,600 ft. of the Burton Act to the 20,000 of the treaty. He sarcastically observed that the "growing influence of technical societies" might result in such control of meteorological conditions that ice troubles resulting in intermittent service might be avoided. He appeared to think that much influence might be exerted by associations of industries dependent upon electrochemical products—this, one presumes, on public opinion and legislation, not on ice. Two points from his remarks aroused general interest—first, his admission that "if the power companies had been together in anything beside their woes, conditions might have been very different;" secondly, his estimate that the total flow of the falls represented about 5,000,000 hp., and his contention that a suitable system of submerged weirs could so distribute the flow as to render 60 per cent available for power purposes and provide a grander spectacle than at present with the remaining 40 per cent, while at the same time diminishing the natural erosion at the peak of the horseshoe where the large volume of water is now running over without assisting the spectacle in the least, but resulting in the recession which tends to denude the remaining portions of the fall of water.

In answer to a question Mr. Harper said that the Niagara Falls Power Company generated 90,000 hp. and the Hydraulic Power Company 100,000 to 125,000. All the latter, except 15,000 hp., was employed in the electrochemical industries.

F. J. Tone, who followed, spoke on the subject of *Niagara Power and Industrial Self-Containedness*.

This concise statement would lose so much by summarizing that it is quoted in full:

If the year 1915 has shown us one thing more clearly than another, it is that a nation must be economically and industrially independent. Some of our economists have told us from time to time that a nation should not strive to be self-contained; that America should confine itself to the development of its most abundant resources, for example, those of agriculture, lumber, coal and the heavy manufacture of iron and steel, and that we should let Germany supply us with our potash, dyestuffs and fine chemicals, England with our ferromanganese and Chile with our nitrates.

The year 1915 has shown us to what economic distress such a policy leads. We have seen crude potash advance from \$35.00 to \$400.00 per ton—a point where its use as a fertilizer has practically ceased. We have seen England place an embargo on ferromanganese and the price advance from \$38.00 to \$125.00 per ton. Magnesia, the basic refractory of the steel manufacturer, has become almost unobtainable, and the same may be said of numberless commodities, including emery, barytes, carbolic acid, crucible graphite, platinum and dyestuffs.

I wish to point out a few ways in which the whole question is bound up in Niagara power, and to show the paralysis of industry that would follow if the electrochemical companies of Niagara Falls could not continue to meet the call that is being made on them. Few realize how many industries are directly dependent on chemistry. Still less has it been realized to what extent our great basic American industries depend on electrochemistry, and specifically on the electrochemical products of Niagara power.

I first wish to mention the steel industry. The manufacturers of steel, the greatest of all American industries, are to-day absolutely dependent upon Niagara power by reason of its requirements in ferro-alloys, such as ferrosilicon, silicon metal, ferrochrome and ferromanganese. In 1915 there was produced in this country about 28,000,000 tons of steel, 20,000,000 tons of which was basic open-hearth steel, and in 75 per cent of this there was used as the main deoxidizing agent high-grade ferrosilicon produced in the electric furnace by Niagara power. All ferrosilicon made by electric furnaces in America is now produced from Niagara power.

It is an absolutely essential element in 15,000,000 tons of steel.

The most striking example, however, of the intimate relationship between the metal working industries and Niagara power is that of high-speed steel. The essential alloys in the manufacture of high-speed steel are ferrochromium, ferrotungsten and ferromanganese. All of these are produced in Niagara, and they are also made elsewhere by the use as reducing agent of metallic aluminum, likewise a product of Niagara power. If the supply of high-speed tool steel were cut off there are hundreds of metalworking industries where the output would be reduced to 25 per cent of their present rate.

Ferrochrome is also the hardening element in armor plate and armor-piercing projectiles, and not a battleship is afloat but what has many tons of it in her armor; yet up to three years ago we were dependent on Europe for one-half of our supply.

In other special steels, such as silicon steel or electrical transformer steel, we also find an almost total dependence on the products of Niagara power.

The abrasive industry is one intimately connected with industrial life. Without adequate grinding materials the most important industries of the country, including the manufacture of automobiles, agricultural machinery, steel and malleable iron, marble, granite and all finished products of iron and steel, would be greatly handicapped and in cases their output would be reduced to a fraction of their present rate. The abrasive situation to-day is another striking illustration of the dependence of industry on Niagara power.

Abrasives are of two kinds; the natural abrasives, which are Turkish and Grecian emery, and the artificial abrasives, such as carborundum, alundum and aloxite. Ten years ago artificial abrasives represented 22 per cent of the total consumption. In the year 1914 they represented 55 per cent. Since the war, however, the mining of emery has almost ceased. Not a pound of Turkish emery is being shipped, and shipments from Greece are negligible.

There are four artificial abrasive plants operating with Niagara power, and they produce all the artificial abrasives used in this country. Their annual output is about 20,000 tons. If this supply were cut off a partial paralysis would follow throughout the metalworking industries.

As an example, take the automobile industry. One of the big western manufacturers plans during 1916 to put out 1000 cars per day. In the factories of that company grinding machines form about 25 per cent of the tool equipment. The crank shafts are roughed and finished with grinding wheels, the cylinders are bored with grinding wheels, balls and ball bearings cannot be produced without grinding wheels. It takes 500 wheels per month to grind forgings alone. If we could conceive that these works were forced to go back to the grindstone and were at the same time deprived of high-speed tool steel, aluminum, oxyacetylene welding and other products produced by Niagara power, it is not an exaggeration to say that their output would drop from 1000 to 100 cars per day, with the same plant equipment and the same number of workmen. The cost of the car would be multiplied by ten, which simply means that there would be no automobile industry.

Aluminum and calcium carbide, the largest of the electrochemical industries from the point of the power consumed and value of the products, were first made possible by Niagara power, and on these products, as well as other Niagara products, such as bleaching powder, alkali, chlorine, phosphorus, graphite, sodium and cyanides, depends a whole line of America's basic industries.

To-day nitrogen products are unquestionably the most important products in the field of chemistry. Without them modern warfare, as we know it, would be impossible, because they are an essential element in every explosive.

The success of Germany in making herself independent of Chilean nitrates in a single year is an industrial achievement of the highest order, but nitrates are not merely a war product. They are necessary in the life of an agricultural nation at all times and, as a matter of common foresight, the production of artificial nitrates should to-day be made an established industry in America. This does not mean that we should at once produce all the nitrates required, but partial development should be encouraged, which would enable the industry to be perfected in its chemical and technical organization so that it could meet any natural or political emergency. This at once calls for cheap electrical power in the center of good transportation facilities, and, in brief terms, it means that we must have Niagara power in large amounts and at low cost.

The only nitrogen fixation works operated by Niagara power is the American Cyanamid Company, and this pioneer industry was forced to go to the Canadian side to obtain

sufficient power. America has 25,000 horsepower devoted to nitrogen fixation and Europe over 300,000 horsepower. We are startled when we are told that for the spectacle of Niagara we are paying the price of a million tons of coal a week. I believe it is more startling to put this in terms of America's food supply. If Niagara was devoted to the production of nitrogen fertilizer it would produce sufficient nitrogen for 3,000,000 bushels of wheat per day.

In any program of industrial preparedness and self-containedness chemical preparedness and chemical self-containedness play a big part, and its crux is more Niagara power.

L. E. Saunders elicited from P. P. Barton of the Niagara Falls Power Company the statement that from 125,000 to 150,000 hp. was being transmitted into the United States from the power stations on the Canadian side at Niagara Falls. Mr. Saunders pointed out that this importation depended on permits revocable by the Canadian government, and indicated that the revocation of these permits was not so distant as people imagined. The generation of large quantities of additional power at Niagara on the American side, and rapidly, was the only way by which a frightful dislocation of American industry could be avoided.

H. R. Carveth stated that it was necessary, as development of power had been restricted by popular voice, and as popular opinion traveled as a pendulum swings, to take advantage of the return swing from the influence of the J. Horace MacFarland *Ladies' Home Journal* agitation. It was a question whether the return swing had already started or not.

NIAGARA FALLS POWER AS A NATIONAL DEFENSE NECESSITY

Albert H. Hooker spoke of the present campaign for national preparedness, and considered a much larger development of Niagara Falls power as a national defense necessity.

The largest industries of the country, steel, paper and chemicals, now find these electrochemical products vital raw materials without which they cannot operate. Many of these products so useful in times of peace are called for in vastly larger quantities in times of war. Not only the equipment, but the skilled electrochemists, mechanical engineers and operators are needed for the manufacture of these products. The provision of such skilled labor in these specialized industries in times of peace, as an emergency measure, is fully as important as compulsory military service and should be considered as a branch of the same broad plan. As regards the electrochemical industry such development could only take place where economic conditions were favorable for the economical production of power of the highest commercial value. For this industry, Niagara Falls occupied first rank and now holds first place as the world center of the industry, with the greatest force of active workers in this field anywhere in the world.

Even now some of our industries were compelled through lack of power to move to Norway and other fields, while unused water which could be consumed without injury went to waste and we start the training of a foreign army of electrochemical workers on foreign soil.

Germany's interest in the electrochemical industry and the fixation of nitrogen has been her salvation at this time, and we should consider her interest in the dye industry as a measure of preparedness. The same benzol, toluol, caustic soda, nitric acid, chlorine and sulphuric acid used in times of peace in the manufacture of dyes are used in times of war for the various nitro explosives; the same equipment is used and the same army of skilled chemists and workers familiar with the latest details of nitration processes are in constant training. Should we not consider the

training of this industrial army and the development of our water power and electrochemical industries as of particular importance now as a matter of preparedness in National Defense?

After some further discussion, on the motion of Mr. Saunders, the chairman appointed a committee of the Section to deal with the matter along the lines suggested in the discussion. The chairman appointed F. J. Tone (chairman), H. R. Carveth, I. R. Edmonds, F. A. J. FitzGerald, A. H. Hooker, H. W. Kellogg, W. S. Landis, F. A. Liddbury, C. H. Moritz, L. E. Saunders, W. A. Smith, A. T. Hinckley (secretary).

The Western Metallurgical Field

Potash from Kelp

The Hercules Powder Company has let a contract to Charles C. Moore & Company of over \$500,000 for the erection of a kelp plant in San Diego, Cal.

Swift & Company are also building a new potash plant at San Diego, having completed their experimental work in the plant which they leased for that purpose in San Diego.

Cooperation Between U. S. Bureau of Mines and Colorado School of Mines

On Jan. 29, 1916, a cooperative agreement was signed by Van H. Manning, director of the United States Bureau of Mines, and William B. Phillips, president of the Colorado School of Mines, which is expected to react to the benefit of both parties and to aid in the metallurgical development of the State. The present Denver office of the bureau is to be removed to Golden next June, and thereafter metallurgical research will be conducted under joint auspices. Under the terms of the agreement the school offers the bureau the use of the building known as Engineering Hall, which will be slightly remodeled to meet the bureau's needs.

This arrangement has been concluded with the object of avoiding duplication of work; to obtain an interchange of information; and to cooperate in the conduct of investigations having particular reference to the development and utilization of the mineral resources of Colorado and the West. The experimental mill and testing plant of the school will be available for this work as far as may be necessary, and in general the laboratory and library facilities will be at the disposal of the bureau.

Details of the work that will be undertaken and the exact method of cooperation have not yet been determined, and will be left to the discretion of the proper officials of the school and the bureau. It is recognized by all concerned that the success of the arrangement depends on active and genuine cooperation, and it is expected that harmonious relations will be established and that the industry will profit from the close contact of these two centers of metallurgical research.

Improved Industrial Relations in Colorado

The marked change that has come over the spirit of capital and labor in Colorado since the war-like conditions of 1914 is reflected in the *Industrial Bulletin* of the Colorado Fuel & Iron Co. This company is one of the largest employers of labor in Colorado, operating numerous coal mines and the Minnequa steel works at Pueblo. In former years there has been more or less disagreement between the company and its employees, culminating in actual warfare two years ago this spring. Echos of those conditions are still heard in the courts, where miners are being tried for their part in the destruction of life and property.

Apparently a new day has dawned, and employer and employee are going to understand each other better.

They are coming to a belated recognition of the rights of each, and of the necessity for cooperation for mutual good. It will be remembered that out of the strife of 1914 grew a proposal of the junior Rockefeller for industrial representation among employees and company officials, for the purpose of harmonizing differences of opinion. That plan is now being put into effect, and conferences have been held. The president of the company has appointed an "industrial representative" for mines and one for the steel works, their duties being indicated by their official titles.

In the January issue of the company's *Industrial Bulletin* we note an editorial on "Democracy in Industry," from which we quote a few lines that show the tenor of the new relations: "The growth of large corporations seems to demand some such step as a means of insuring justice to every employee. In large measure this plan brings all employees of the company into close relations with the officers, somewhat as was possible in the old days when the individual employer with a small group of employees took a personal interest in the welfare of each member of his business family. There are many honest critics who regard this as paternalism and as doomed to failure. But there is every evidence that C. F. & I employees believe that a real partnership of these two interests is possible—a partnership based on friendship, mutual interest and fair dealing. This company is squarely committed to democracy, as contrasted with paternalism, in all its relations with its employees."

Engineering Research Proposed for Columbia

In the annual report of Dean F. A. Goetze of Columbia University he discusses the proposition of establishing at Columbia an engineering research laboratory similar to those in Germany which he visited some time ago. The proposed scheme is pretentious and involves the expenditure of about \$500,000 for building and equipment, and an endowment of from two million to five million dollars. In comparing the relative cost and value of the proposed engineering research laboratory with that of the proposed building for applied science on the university site, Dean Goetze states that "with the same amount of money we could buy a site with railroad and water facilities within five minutes' walk of the university, erect on it a building twice the size, of a modern factory construction much better suited to our purposes, and have about \$150,000 left over for equipment." After speaking of the endowment he expresses the opinion that "no other university is so favorably situated by its environment, prestige and traditions to lead in this important field."

Conditions in Mexico

The recent massacre of members of an engineering party in Mexico has acted as a bar to the early resumption of work at some mines. The conditions which resulted in this sad incident have not been confined to any one part of the country, and bandits are active wherever they feel reasonably secure from molestation by agents of the *de facto* government. In a recent letter from an engineer now at Guadalajara, commenting on the fate of the engineers in Chihuahua, he says: "We walked into a trap like those poor devils did, but thanks to four of our men who learned of it in time and who caught the bandits in the rear just as they were about to attack us, we got away and back to Ixtlan, while the bandits scattered after losing one man. We got an escort and returned, but found none awaiting us that trip." Such conditions speak for themselves and show what prospect American engineers have in starting or continuing mining and milling operations in Mexico. It is more

than likely that such conditions will prevail for some time to come, and life and property will be in jeopardy. Sporadic outbreaks will occur, becoming less frequent as time goes on, with bandits pillaging and murdering, until the government becomes strong enough to insure peace. In the meantime American engineers apparently are without assurance of safety while remaining or traveling in Mexico.

Company Reports

The seventh annual report of Stratton's Independence, Ltd., contains a resume of operations for the seven years of the company's existence, and an interesting comparison of the results actually obtained with those anticipated by the original tests of the dump. For the year ended June 30, 1915, the mill treated 116,778 tons of ore, of which 74,849 tons came from the old dump and the balance from the mine. The average gold content was but 0.1468 oz. per ton. There was recovered in concentrates 37.31 per cent of the total, and in bullion 38.66 per cent, or a total of 75.97 per cent. The first-grade concentrate averaged 4.031 oz. gold per ton and the second-grade 1.61 oz. These products were sold to smelters. The following table gives a summary of milling cost:

Operation	Per Ton
Coarse crushing and sorting.....	\$0.199
Fine crushing, concentrating and treating concentrate.....	0.515
Cyaniding and special chemicals.....	0.478
Miscellaneous expense	0.171
Total milling cost.....	\$1.363
Mining dump ore.....	0.150
Total cost	\$1.513

Compared with the previous year the tonnage treated was less, the extraction lower and the cost higher.

Mr. Argall, consulting engineer, who originally recommended the construction of the mill and the treatment of dump ore, adds some figures to show how his estimates have been confirmed in practice. The estimated value of the dump ore, obtained through the expenditure of \$9,500 for sampling, was assumed to be \$3.60 per ton. Based on a 70 per cent extraction and an operating cost of \$1.52 per ton, Mr. Argall believed that a net profit of \$1 per ton could be made. A summary of six years' milling operations shows the treatment of 671,665 tons of ore containing an average of 0.1522 oz. gold per ton, yielding an average extraction of 74.57 per cent at a cost of \$1.5138 per ton. Thus it is seen that the average value of the ore was slightly lower than the estimate; the recovery was considerably higher and the cost slightly lower. If a monthly tonnage of 10,000 tons had been treated continuously the net profit of \$1 would have been fully realized.

Throughout its history to the date of sale to the Portland Gold Mining Co., Stratton's Independence mine produced ore of a gross value of \$23,621,728, yielding earnings amounting to \$8,116,778. The present company paid in dividends \$455,625 and had cash on hand, after selling the property for \$372,000, amounting to \$510,000. Having closed its business in the Cripple Creek district of Colorado, the company is now looking for a new property.

The report of Camp Bird, Ltd., for the period ended June 30, 1915, shows that both profit and tonnage for the year exceed the estimate of a year ago, and that there still remains in reserve a profit almost equal to the estimate of a year ago. Cost of both mining and milling are lower by 12 cents per ton each than they were during the previous year. The total cost of operation is lower by 98 cents per ton. The profit amounted to \$583,700, an increase of \$186,380 over the preceding year. The mills were in operation 357 days, and the saving was 96.03 per cent of the gold value and

94.31 per cent of the combined gold and silver value. Of the total recovery, amalgamation yielded 58.48 per cent; concentration, 36.59 per cent; cyanidation, 4.93 per cent. The recovery of metals per ton of ore averaged 1,333 oz. gold, 3.78 oz. silver, 1,048 per cent lead and 0.16 per cent copper. The value per ton of the recovered metals was \$29.47, as compared with \$26.19 last year. The amalgamation and concentration mill treated 32,313 dry tons of ore. The cyanide mill treated 20,655 tons of tailings from amalgamation and concentration. Dividends paid amounted to £100,476 (\$487,308).

The Santa Gertrudis Co., Ltd., states in its annual report for the period ended June 30, 1915, that operations at the property in Mexico have been practically continuous under the adverse conditions that have existed. Development work has continued, and the ore reserves are estimated at 1,287,000 dry tons, sufficient to last about three and a half years under normal conditions of production. The estimated metal content in the ore reserves is 81,086 oz. gold, and 16,217,296 oz. silver, 90 per cent of which is recoverable. The Guadalupe mill remained closed during the year, although 268 flasks, or 10.09 tons of quicksilver was recovered from the old patio. Work at the new mill has been far below capacity owing to the difficulty of obtaining supplies. The gross tonnage treated amounted to 211,669 dry tons of ore having a gross value of 26s. 2d. (\$6.28) per ton. The recovery in bullion amounted to 90.31 per cent of the gross value. The average daily tonnage treated was 580 dry tons, compared with full capacity of 1111 tons.

The Coniagas Mines, Ltd., in common with other producers of silver, suffered from the reduced demand and lower price of that metal in 1915, according to the annual report for the period ended Oct. 31, 1915. The concentrating mill at Cobalt, Ontario, ran 98.83 per cent of the possible time, milling 55,437 tons of ore, at the rate of 3.02 tons per stamp per 24 hours. The average silver content was 23 oz. per ton. High-grade silver concentrates amounted to 473.9 tons, containing 2175 oz. silver per ton. Low-grade slime, averaging 233 oz. silver per ton, amounted to 133 dry tons. Sand tailing contained 2.89 oz. silver, while slime tailing carried 6.36 oz. per ton. The average tailing carried 3.94 oz. The high-grade mine ore shipped amounted to 267 dry tons, containing an average of 3520 oz. silver per ton. Total shipments of silver for the year amounted to 2,002,053 oz. The cost of mining and concentrating was 13.618 cents per ounce of silver produced. The cost of shipping, smelting, refining and marketing was 3.252 cents per ounce. Dividends amounting to 21 per cent, or \$840,000, were paid. Silver reserves are estimated at over ten million ounces. An addition to the mill is under construction for the purpose of cyaniding about 6 tons per day of low-grade canvas table concentrates and decomposed slime or gouge from the mine. It is estimated that this plant will effect a saving of about \$100 per day.

The Consolidated Mining & Smelting Company of Canada, Ltd., made a net profit of \$795,411 during the year ended Sept. 30, 1915, after writing off \$192,479 for depreciation. Dividends amounting to 8 per cent, or \$464,398, were paid, leaving a balance of \$331,013. The total credit to profit and loss account is \$2,058,300. Important additions have been made at the smelter to provide for the production of refined zinc and copper. The manufacture of zinc is a new departure, but is expected to develop into an important feature of the company's operations. Copper matte, hitherto refined in the United States, is to be refined in Canada. Further improvements consisted in purchase of the right to use the Cottrell process of fume recovery for roasters and blast

furnaces; construction of an additional lead furnace; construction of a new lead sampling mill. The experimental electrolytic zinc plant was operated during the year, producing spelter of good grade at the rate of $\frac{1}{2}$ ton per day. A permanent plant of about 35 tons daily capacity is now under construction. Smelter production for the year amounted to 148,891 oz. gold, 2,230,500 oz. silver, 40,177,910 lb. lead, 5,306,184 lb. copper, all from 447,064 tons of ore and of a gross value of \$6,898,744.

The Iron and Steel Market

Steel prices have advanced during the past fortnight more rapidly than ever. On Feb. 15 steel pipe and line pipe, 12-in. and under, was advanced one point or about \$2 a ton, oil country goods being advanced \$2 to \$4 a ton, while wrought-iron pipe was likewise advanced \$2 a ton. At about the same time wire products were advanced \$2 a ton. On Feb. 17 the Carnegie Steel Company advanced bars, plates, shapes and hoops \$5 a ton, previous advances having generally been \$1 or \$2 a ton, and other mills immediately followed in this action. The price of \$3.75 on tin plate, which had been gradually disappearing, became altogether nominal, yielding to an actual market of \$4 to \$4.25 for 100-lb. cokes.

The attitude of the mills in advancing prices so sharply, when they were already at the highest level in a dozen years or more, is not clearly disclosed. As a rule when the mills advance prices it is because they have booked all the business they care to book at a certain level but are prepared to book a considerable additional tonnage at a higher figure. In this instance they are still reserved about selling. Either they expect practically fabulous prices to be paid for large tonnages of steel in future or they feel that a break in prices would not be the formidable event it usually is.

The average price of finished steel products, including bars, plates, shapes, pipe, wire, sheets and tin plate, weighted approximately according to their tonnage importance, has advanced from 1.42c. in December, 1914, when the lowest level in fifteen years obtained, to 2.07c. at the close of 1915, equal to the average level of 1907, and to 2.42c. at the present time, representing a total advance of \$20 per net ton, two-thirds of the advance having occurred during 1915 and one-third during the first two months of this year.

There is a divergence in the extent to which the mills are definitely sold up and the extent to which they are committed to customers. The Steel Corporation's statement of unfilled obligations at the end of February, to be made public March 10, will probably show it sold up, on an average, to the latter part of September. It is not certain that all the tonnage will actually be taken by customers, while on the other hand there are promises to take care of regular customers, representing important additional obligations which preclude the acceptance of much tonnage from new buyers. Many steel buyers appear to be quite fearful that the regular sources of supply will be unable to furnish them all the steel needed during the second half of the year.

Pig-iron production is at the rate of about 39,000,000 gross tons a year, production of ingots and castings at the rate of about 41,000,000 tons, and production of finished rolled steel at the rate of about 29,000,000 tons. The production of pig iron has been a surprise for months, or ever since it passed a rate of 36,000,000 tons, representing approximately the estimates made of the existing capacity, based on performance the last time the industry was really active. The blast furnaces have outdone themselves. A large part of the excess production appears to be due to the fact that many furnaces have been provided with larger hearths, the change bringing about a larger output without a corre-

sponding increase in either the air or coke supplied. There was a time when predictions were made that on account of the heavy building of open-hearth furnaces without the erection of a corresponding number of blast furnaces a shortage in pig iron would occur before a shortage in steel, but the history of the market to date is that finished steel products have advanced an average of \$20 a net ton while pig iron has advanced an average of \$5.50 a gross ton. Comparisons made for the top prices of 1907, 1909 and 1912 show advances in pig iron not dissimilar to the advances in steel.

Pig Iron

The extreme dullness that characterized the pig-iron market for about two months has been suddenly broken in the past fortnight, with respect to steel-making iron. There were large purchases in the East, followed by several important purchases in the Central West, and in the latter region there was also a fair turnover in northern and southern foundry iron, the movement to date representing possibly about a quarter million tons. Prices have not advanced definitely, but consumers have become much more interested. The balance between production and consumption is a very delicate one, with few idle furnaces that are at all fit, and much open-hearth steel capacity under construction. The steel works have small stocks, but may conclude that in such uncertain times as these, and with steel prices advancing by leaps and bounds, it would be prudent to build up reserves. In some quarters there are predictions that pig iron will advance by leaps and bounds, once buyers conclude to act against the possible dangers, and it may be noted that while the furnaces have passed through an apparently trying period of market stagnation they are decidedly reserved about selling. We quote: No. 2 foundry iron, delivered Philadelphia, \$19.75 to \$20.25; f.o.b. furnace, Buffalo, \$18 to \$18.50; delivered Cleveland, \$18.80; f.o.b. furnace, Chicago, \$18.50 to \$19; f.o.b. Birmingham, \$14.50 to \$15; f.o.b. valley furnaces, 95 cents higher delivered Pittsburgh; Bessemer, \$20; basic, \$18; forge, \$18; malleable, \$18 to \$18.50; No. 2 foundry, \$18.50.

Ferromanganese is extremely scarce, bringing \$225 to \$250 for small prompt lots, while the contract price for English, second half or fourth quarter, is \$150, with some English producers not quoting at all.

Steel

The demand for unfinished steel has broadened somewhat, as premiums are obtainable for some descriptions of finished steel, the regular mill prices on finished steel, for forward delivery, not being high enough to justify finishing mills paying prices that would be asked for unfinished steel in the open market. Such mills, are, of course, moderately well covered by contracts. As fairly representing the market in general \$35 may be quoted for Bessemer and \$38 for open-hearth, either billets or sheet bars, f.o.b. maker's mill, Pittsburgh or Youngstown. Rods have advanced to \$50, for deliveries beginning a few months hence, and a few sales have been made at this remarkable figure, which is higher per pound than the regular market on plain wire.

Finished Steel

Regular prices given below are f.o.b. Pittsburgh, unless otherwise noted, and for delivery at mill convenience, the higher in a range of prices being for early delivery of small lots.

Rails, standard sections, 1.25c. for Bessemer, 1.34c. for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 2.35c. to 3c.

Structural shapes, 2.25c.

Steel bars and bands, 2.25c. to 2.75c., base; steel hoops, 2.50c., base.

Iron bars, Philadelphia, 2.409c.; Pittsburgh, 2.20c. to 2.30c.; Chicago, 1.90c. to 2c.

Plain wire, 2.15c., base; galvanized wire, 2.85c.; wire nails, \$2.30, base; painted barb wire, 2.45c.; galvanized barb wire, 3.15c.

Sheets, blue annealed, 10-gage, 2.65c. for Bessemer, 2.75c. for open-hearth; black, 28-gage, 2.60c.; galvanized, 4.75c. to 5c. basis.

Tin plate, \$4 to \$4.25 for 100-lb. cokes.

Steel pipes, 3/4 to 3-in., 75 per cent off list; galvanized, 59 1/2 per cent off list.

Boiler tubes (less than carloads), 64 per cent off list for steel, 60 per cent off list for iron.

Structural rivets, 3c.; boiler rivets, 3.10c.; cold rolled shafting, 40 to 35 per cent off list; cold rolled strip steel, 4c., base.

Continuous Operation of Engine-Driven Electrolytic Generators

The following table gives the number of hours of operation and the percentage of time that generators were in service at the Raritan Copper Works, Perth Amboy, N. J., from August to December, 1915.

Month	Engine No. 1			Engine No. 2		Engine No. 5		Engine No. 6		Per Cent Total All Engines
	Total Hours in Month	Hours in Operation	Per Cent	Hours in Operation	Per Cent	Hours in Operation	Per Cent	Hours in Operation	Per Cent	
Aug.	744	662	89	575.25	77	740.25	99.7	739	99.2	91.5
Sept.	720	719.5	99.9	705.25	98	703	97.6	715	99.4	98.6
Oct.	744	713.25	96	718	96.5	736.5	97.5	724.6	97.5	97
Nov.	720	691.25	96.1	698	97	696	97	683.6	95.0	96
Dec.	744	732.6	98.5	733.25	98.5	740.5	99.8	742.25	99.9	99
	3672	3518.35	96.0	3429.75	93.4	3606.25	98.5	3604.35	98.2	96.4

The engines are four-cylinder, triple-expansion, Corliss size 21, 38, 44 and 44 by 48, driving 900-kw. generators and were built by the Nordberg Manufacturing Co., Milwaukee, Wis.

The engines, as noted in the table, operated in most cases over 95 per cent of the time, averaging out of the total time in five months 96.4 per cent continuous operation. The time lost was for the most part in keying up and taking up lost motion in valve gears.

The chief engineer of the Raritan Copper Works is Mr. George L. Fales, to whom a large share of the credit for this operating record is due.

Non-Ferrous Metal Market

Copper.—The strained situation in copper continues. The prices here are the highest since 1873. Producers are unable to supply any copper before April or May and in some cases later. Third quarter deliveries are being contracted for. July and August deliveries are quoted at 27 1/4c. with spot at 28c.

Tin.—A rise of 2 cents per pound has been recorded and Straits tin is now quoted at 43.25 f.o.b. New York. The market is very irregular and no consistent demand has arisen although good buying takes place spasmodically. Arrivals up to the 25th were 3752 long tons.

Lead.—Lead still remains in its strong position and in view of the reported demand and sales which are hard to verify the advance made on the 14th to 6.30, New York, was very conservative. This price now rules although another advance would not be surprising.

Spelter.—Spelter is firm and higher. Third quarter is offered at 16 1/2c. eastern St. Louis. Second quarter is

offered at 18c, April at 19c and March at 20c, while spot is quoted at approximately 21c.

Other Metals.—Aluminium is scarce and has risen to 60-61c. There is no relief in sight. Antimony is also hard to obtain as it is claimed that seven-eighths of the arrivals are delivered on contract. The American Daily Metal Market gives the spot price for American, Chinese and Japanese as 43.50—44.50. Silver is quoted at 57. Platinum remains normal at \$88 to \$100 per ounce, while quicksilver is quoted at \$275 to \$290 per flask.

New York Meeting of American Institute of Mining Engineers

The one hundred and twelfth meeting of the American Institute of Mining Engineers held in New York City from Feb. 14 to 17, was a great success and very well attended. The newly elected officers as announced at the business session are Dr. L. D. RICKETTS, president; Karl Eilers, J. MacNaughton, T. B. Stearns, C. F. Rand, C. W. Goodale, E. Ludlow and G. B. Barron, directors. The amendment to the constitution raising the dues from \$10 to \$12 has been adopted. The business session was opened by the masterly presidential address of the retiring president, Mr. W. L. Saunders.

For the arrangement of an unusually attractive program of entertainments and for the vigor with which everything possible was done to make the visitors feel at home and happy, the local committee and its genial chairman, Dr. David H. Browne, deserve the highest praise. The four issues of the *Daily Fume*, published by courtesy of the *Engineering & Mining Journal* furnished much amusement and were greatly appreciated.

The smoker held Tuesday night was a most enjoyable affair and everyone who attended it was enthusiastic in his praise. Mr. L. Addicks had started the arrangements, but sickness prevented him from being present, and the affair was in charge of Mr. David H. Browne and Mr. T. T. Read. There was a most remarkable speaking doll, presented by Mr. Stearns, some grand poetry by Colonel Hay, a metallurgical cow, demonstrated by Mr. Browne, songs, refreshments, and last but not least, a really wonderful experimental lecture on flotation by Mr. Gilbert Rigg, besides a few speeches in more serious mood by some of the oldest members of the Institute. The annual banquet followed by dancing was held on Wednesday night at the Hotel Astor, while the excursion on Thursday on board of the Dolphin was enjoyed by about 200 gentlemen and 100 ladies; despite the inclemency of the weather a delightful time was had by all and many interesting features of the Brooklyn Navy Yard and Sandy Hook proving ground were witnessed. At Sandy Hook a mine was fired but owing to the fog it was not possible to fire the big guns.

The technical sessions were held according to program and all of them quite well attended.

The Relation of Clay to Ore-Dressing and Cyanidation

The presence of clay in so many ores makes a careful study of its relation to metallurgical processes a matter of great importance. A recent contribution on the subject is made by Mr. A. W. ALLEN in *Bulletin* No. 135, Inst. of Min. & Met. Empirical knowledge on the subject of clays in ore-treatment has been gained from the difficulty of settlement, dewatering and filtration, the low recovery of metal, and the problems encountered in classification as a result of the decrease in fluidity of the pulp. The customary explanation has been that oxygen has been absorbed during weathering, resulting in decreased solution-efficiency in cyanide

solutions. Later studies have shown the difference between colloidal and non-colloidal clay, and in the former material is recognized the source of much of the trouble in ore treatment. The author confines his discussion to the properties and influence of colloidal clay.

The absorptive powers of clay depend on their colloidal or non-colloidal condition, the former being highly absorbent and the latter practically non-absorbent. The change may be brought about by weathering, when non-absorbent, non-colloidal clay will change to the other form. Adsorption is a different phenomenon, and refers alone to surface concentration of a substance which clay has removed from a solution with which it is in contact. Adsorption undoubtedly occurs with colloidal clay, and metals may be adsorbed. The adsorptive nature of colloidal carbon, which has recently been prepared, when brought into contact with gold-bearing cyanide solution, might well form the basis of research.

The adsorption of metallic gold is an improbability when consideration is paid to the fact that the gold-potassium-cyanide compound is dissociated in the presence of water into K ions and AuCy₂ ions. If the latter act as electrolytes by which gold is deposited in place of calcium, then the action is the result of milling in gold-bearing cyanide solution in place of alkaline water, and may be suggested as an explanation to account for the experience of Hutchinson, which is borne out by myself and others, that treatment, after crushing in cyanide solution, necessitates a longer time for the recovery of the gold than is required when the ore is crushed in water and given a preliminary alkaline treatment.

It is also interesting to note that the problem of clarification of solutions after milling-in-cyanide is invariably obtrusive, whereas after milling-in-water trouble is seldom experienced in this direction. In other words, the electrolytic value of gold-bearing cyanide solution is inferior to that of lime water; and when once the slime particles are charged with the former no addition of lime will materially hasten coagulation.

A further and perfectly reasonable assumption may be made, that the gold in the finest condition and associated with the ore may be in the colloidal state. Any clay may actually absorb gold either during or after the process of water absorption. Marshall and Welker have shown that colloidal aluminium hydroxide in the form of a thin jelly is capable of completely absorbing gold from its colloidal solution. This aspect of gold absorption may not need more than passing mention, although it may have a greater bearing on gold recovery processes than we are inclined to admit at the present time.

It is more than likely that gold and silver compounds will be absorbed into the structure of the colloid. Their complete recovery by washing may be either impossible or impractical. Hence our present-day ideas as to the method of distinguishing between dissolved and undissolved gold and silver may have to undergo considerable modification. Metals which cannot be rapidly washed out from colloidal clay may not necessarily be undissolved; and, indeed, it is more than probable that they were, in part at least, first dissolved and later absorbed. This fact is borne out by the results of concentration experiments on slime residue, which have failed to isolate any portion of the material having a higher metal content than any other.

This matter of absorption has a direct bearing on the subject of displacement of dissolved solution from slime pulps.

In wet processes of ore reduction, and when clay compounds are milled and treated in a cyanide solution containing gold, it would seem probable that an absorption of such solution occurs in the honeycomb cells of

the colloid, and that subsequent displacement of this metal must necessarily occupy a much longer time than did its absorption. The absorption is due to direct imbibition, but displacement under normal conditions is probably due to a slow-acting osmotic pressure when the colloid slime is surrounded with wash solution or water. It is also probable that any absorptive equilibrium is only temporary under such conditions, and that cell content varies with the composition of the surrounding medium.

The question arises as to the relative merits of a slow decantation as compared with a rapid filtration process for the removal of the dissolved metal. It would seem that a combination of the two, in the order stated, would be the most efficient.

It is generally recognized among metallurgists that a considerable time of contact is necessary in washing operations with certain classes of ores; and that theoretical displacement figures do not hold good in practice. From what has already been said, it is apparent that time of wash should not always be based on estimates of gold in solution which is apparently dissolved, as compared with gold associated with the ore which is apparently undissolved. In practical work it is generally found that, although the metal which has been dissolved may be apparently replaced fairly rapidly by ordinary means, a further abstraction of metal from ore occurs after prolonged contact with wash solution. This fact would furnish additional evidence that the gold solution so recovered is, in part at least, being drawn from the cells of the colloid slime, and not merely washed off the surfaces of the slime particles.

If we admit the absorptive nature of colloidal clay, we must relegate the phenomenon of adsorption to a position of less prominence than it has hitherto been afforded.

The decrease in fluidity of an ore pulp in wet crushing operations due to inclusion of clay has been observed to have ill effects on the efficiency of classification and concentration. The author suggests the benefit of desliming prior to classification, as well as the use of vertical sided settlers instead of spitzkasten, and vertical sided classifiers instead of cones to prevent the accretion of viscous clay on the sides of the vessels. He also cites the following experience with the settling of a clay pulp: The ore contained considerable clay, both intimately associated and as pellets and balls of plastic material. As the amount of colloid material increased the thickening efficiency of the settlers decreased, and as soon as fine slime commenced overflowing the thickeners all dewatering had stopped and the underflow contained as much moisture as the feed. Classification became completely disorganized and fine sand was so buoyed by the viscosity of the pulp that traversed the radius of the thickeners and overflowed. The particles of clay were in the gel form, and no addition or reduction in the amount of lime had any appreciable effect in hastening settlement. Failure to settle was due to the absorption of large amounts of water by the clay, and although the clay entered the mill as unavoidable waste it left in the residue carrying gold that could not be recovered by ordinary washing methods.

The foregoing ill effects of colloids were corroborated experimentally as follows:

A sample of colloid slime, free from sulphides or organic matter, and carrying neither gold nor silver, was obtained. This was finely pulverized and agitated for six hours with an alkaline cyanide solution of normal cyanide content, and carrying 6.6 dwt. of gold per ton. At the end of this time the pulp was divided into two parts. One portion was drained of surplus solution until the slime carried a moisture percentage of 75, care-

fully dried, and assayed entire. The result of the assay was 8.2 dwt. per ton, which showed an adsorption and absorption of, approximately, 3.25 dwt. per ton.

The other portion was thoroughly washed with water by numerous decantations. The excess wash was then removed as far as practicable and the residue carefully dried and assayed. The result showed a gold content of 1.8 dwt. per ton.

Three separate samples of the same material were then agitated with alkaline cyanide solution of graduated gold content. After settlement the supernatant solutions were filtered and assayed, and were found to have lost an amount of gold which was in proportion to their original gold content.

If experiments are made with colloidal clay a number of points are noticeable with regard to the question of settlement. The first of these is that coagulation does not take place until after a definite minimum concentration of lime has been reached in the solution. This point of coagulation is generally marked by a distinct color change—a characteristic of colloid transition from the sol to the gel form. An iron-stained slime will lighten in color as soon as the critical point is reached, and the change is often so marked that mill men adopt it as an indication that a sufficiency of lime has been added.

The second point to be noticed is that settlement is slow at all times, but increases from minimum to maximum in direct ratio to the concentration of the lime in the solution. This rate of settlement is hindered if an excess of lime is added.

If caustic soda is used in place of lime we find that it is of considerably less value as an electrolyte; also, that a proportion of the colloid is not precipitated whatever concentration of the solution is aimed at.

In perfectly neutral solutions of colloids in the emulsoid form electrical action is almost absent. In ordinary work, such as the operation of the cyanide process, neutral solutions are seldom or never found; hence we may assume that coagulation and settlement are controlled by electrical action. It will, therefore, be mundane to consider briefly the factors governing the situation.

Lime is generally used as a neutralizer to counteract latent or formed acidity, and it is also used as an electrolyte to ensure coagulation and assist settlement. We have seen how it may and probably does act as a coagulator. This is doubtless due to the combination of the calcium ions with the slime particles. We also know that an excess of lime hinders settlement. This is due to the reduced conductivity which follows concentration of the electrolytic solution.

In summarizing his experience and work the author finds that a complete extraction of gold from even the finest slime is impracticable; that the cyanidation of accumulated clay slime often results in a lower extraction than would have been obtained had the slime been treated directly as made; that the milling a clayey ore in a gold-bearing cyanide solution invariably necessitates longer time for treatment and results in a higher residual metal content than would have been the case had it been milled in alkaline water; that the facts adduced indicate the high absorptive power of colloidal clay, enabling it to retain liquids and dissolved salts. Adsorption may occur during treatment, but the main loss is due to absorption. Non-colloidal clay is only slightly absorbent; colloidal clay, highly absorbent; burnt clay, after the colloidal envelope has been destroyed, practically non-absorbent. The weathering of clay slime should be avoided unless it is desired to decompose some refractory mineral, and clay slime should be given an extended time of contact with wash solution.

The Effect of Temperature on the Formation of Olefins from Petroleum at Atmospheric Pressure

BY GUSTAV EGLOFF AND THOMAS J. TWOMEY

It is well established that the cracking of petroleum or a high boiling fraction from petroleum in the gas state yields, besides carbon and gas, cracked oil which has a different composition than the material subjected to decomposition.

For the main part its constituents are the four types of hydrocarbons: (1) paraffins; (2) unsaturated compounds—olefins and acetylenes; (3) naphthenes and (4) aromatic compounds. The occurrence of the latter, however, depends necessarily on the conditions of the cracking. The extent to which any one of these classes may be formed is governed by the factors resulting in the decomposition of the original oil, such as nature of the oil, temperature, pressure and time of reaction which is itself controlled by the rate of flow into the heated zone and by the size of the cracking area. Of all these, temperature has perhaps the largest influence and gives the greatest variations in the amounts and in the character of hydrocarbons present in cracked oil. In a previous communication¹ its effect on the formation of the aromatic type—benzene, toluene, xylene, naphthalene and anthracene—was shown. Since it was found that certain temperatures were not only required for the formation but also resulted in definite relationships between these compounds, it was deemed of sufficient importance to investigate still further the influence of the same degrees of heat on the production of another group of hydrocarbons in the same cracked oil—notably the effect on the formation of unsaturated compounds.

According to the available data in the literature the nature of these unsaturated hydrocarbons have been investigated sufficiently to show in a general manner those common to a cracked oil. Thorpe and Young² found that paraffin on being distilled under pressure at a high temperature decomposed into liquid compounds of the methane and ethylene series. Among the latter were included amylene, hexylene, etc., up to nonylene. Gawalowski³ has found recently that paraffin on prolonged heating changed into gaseous and liquid products, which in both cases belonged to the ethylene and acetylene groups. In the investigation of the "hydrocarbon" resulting as a by-product in the manufacture of Pintsch Gas, Armstrong and Miller⁴ found olefins—ethylene up to nonylene and also crotonylene. Lewes⁵ states that the recovered tar obtained by the cracking of Russian petroleum contained hexylene and heptylene. Kramer and Spiker⁶ distilled a lubricating oil (Baku) under pressure and identified olefins in the distillate which was recovered.

From the work of these investigators it appears that the cracking of high boiling fractions of petroleum give low boiling fractions which among other substances contain unsaturated compounds, mainly those of the olefin series. The research to the present date does not seem to show that members of the acetylene series are formed to any great extent.

No specific data could be found in the literature concerning the direct effect of temperature on the unsaturated hydrocarbon formation. Hall⁷ states, however, "I can say with all assurance that high temperature makes for high unsaturation." This conclusion was derived

from experimental evidence obtained in the operation of his process.

If in cracking an oil by distillation under pressure, the pressure effect may be translated into terms of temperature, a few more examples of the influence of temperature on the unsaturated formation may be had. Distillation under pressure is that type of cracking which takes place in the liquid-gas phase. In this system increased pressure is due to increased temperature. Hence, results obtained by cracking under increased pressure correspond in a manner to those found under increased temperature conditions when the cracking is conducted entirely in the gas phase. In the Burton process the distillate is condensed under pressure because pressure decreases the amount of unsaturation. A statement presented to the United States Patent Examiner gives the sulphuric acid absorption of the Burton distillate as 20.2 per cent and iodine number as 97 against 49.4 and 200 respectively on a similarly cracked distillate condensed without pressure. Brooks⁸ found that cracking Oklahoma petroleum under pressure decreased the refining losses in the gasoline cut besides increasing the amount of gasoline formed. The data constitutes the ground for United States Patent 1,101,482.

Scope of the Investigation

In the present paper it was not the intention of showing the influence of temperature on the individual unsaturated formation, but rather on the total formation in certain distillation cuts. In the analysis of cracked oil for aromatic hydrocarbons produced by cracking a distillate or gas oil derived from a Pennsylvania crude petroleum in the gas state at temperatures 450 to 800 deg. C., distillation cuts were made to 95 deg. C., 95 to 120 deg. C., 120 to 150 deg. C., 170 to 230 deg. C., 230 to 270 deg. C., and 270 deg. C. to Tar.

The object of this investigation was to point out the unsaturated hydrocarbon formation in these cuts. From a combination of values, it was also possible to show: (1) the effect of temperature on the unsaturation in the recovered oil to 95 deg. C., 95 to 120 deg. C., 120 to 150 deg. C., 170 to 230 deg. C., 230 to 270 deg. C., 270 deg. C. to tar; (2) the unsaturated formation in the gasoline cut—to 150 deg. C. This method of procedure allows one to follow the thermal effect on the formation of the unsaturated hydrocarbons in the cuts and also the extent to which the original paraffin oil on being thermolized decomposed to lower and equally high boiling olefins and similar compounds.

Experimental Part

A distillate or gas oil, boiling between 250 and 350 deg. C., derived from a Pennsylvania crude petroleum was cracked in the gas state by passing through a steel tube at atmospheric pressure. Experiments were run at the following temperatures: 450, 500, 550, 600, 650, 700, 750 and 800 deg. C. The per cent of recovered oil obtained, the gas formation, the specific gravity of the recovered oil, the aromatic content and other data will be found in a previous communication.⁹

The recovered oil from each experiment was distilled using an efficient fractionating column for the lower boiling constituents, and final cuts were made to 95 deg. C., 95 to 120 deg. C., 120 to 150 deg. C., 170 to 230 deg. C., 230 to 270 deg. C. and 270 deg. C. to tar.

The per cent of unsaturated compounds in these cuts was determined by means of 95.0 per cent sulphuric acid. The following method of procedure was used: Ten cc. of oil was measured by means of pipette into a Babbcock milk bottle, the neck of which was calibrated in

¹ Egloff and Twomey, Jour. Phys. Chem. 20, 121 (1916).

² Liebigs Ann., 165, 28; Chem. News, 23, 174, 1871.

³ Oesterr. Chem. Techn., Ztg., 70, 1910.

⁴ Jour. Chem. Soc., 49, 74, 1886.

⁵ Jour. Soc. Chem. Ind., 11, 584, 1892.

⁶ Ber., 33, 2265, 1900.

⁷ The Inst. of Petroleum Technologists.

⁸ Jour. Franklin Inst., 180, 653, 1915.

⁹ Loc. Cit.

tenths of a cubic centimeter, one cc. of 95.0 per cent sulphuric acid was added from a burette. The bottle was shaken for five minutes, cooling at the same time in order to avoid heating. Following the same procedure, two, three and four cc. of acid were added. The bottle was centrifuged for three minutes, enough sulphuric acid added to bring the unabsorbed oil upon the scale on the neck and the bottle again centrifuged until no further increase of unabsorbed oil was obtained. The reading of the amount of unabsorbed oil was made, and the unsaturated formation was found by difference.

No extreme accuracy is claimed for the method. It is well recognized that the determination of certain hydrocarbons is beset with particular difficulties because the chemicals used overlap other groups to a greater or lesser extent. In this particular case, the concentrated sulphuric acid, by means of which the unsaturated hydrocarbons were determined, attacks the low boiling aromatics, the naphthalenes and even the paraffins. For

this reason, the method does not lay claim to any great accuracy. All that is claimed is that the method was of sufficient accuracy to bring out in unmistakable terms the effect of temperature on the unsaturated formation.

The first determination for unsaturation was made on the oil used for the cracking experiments. Concentrated sulphuric acid did not have any effect upon it.

The determination of the unsaturated compounds in the cuts was simple to make, although great care had to be taken with the determinations of the lower boiling fractions. The addition of even a small quantity of sulphuric acid produced great heat. For this reason, the oil was cooled before the addition, and immediately held in running cold water to avoid heating. The acid produced a black red sludge, the depth of color of which depended on the amount of unsaturated compounds present.

The experimental results obtained are all based on the determinations in the different cuts. From these data it was possible to bring out the following, which are shown in tables and in figures:

1. The effect of temperature on the per cent of unsaturation in the cuts to 95 deg. C., 95 to 120 deg. C., 120 to 150 deg. C., 170 to 230 deg. C., 230 to 270 deg. C. and 270 deg. C. to tar.

2. The effect of temperature on the per cent of unsaturation in the gasoline cut to 150 deg. C.

3. The effect of temperature on the percentage of unsaturated compounds in the recovered oil in the cuts to 95 deg. C., 95 to 120 deg. C., 120 to 150 deg. C., 170 to 230 deg. C., 230 to 270 deg. C. and 270 deg. C. to tar.

Discussion of Experimental Results

A. THE EFFECT OF TEMPERATURE ON THE FORMATION OF UNSATURATED COMPOUNDS IN THE CUTS TO 95 DEG. C., 95 TO 120 DEG. C., 120 TO 150 DEG. C., 170 TO 230 DEG. C., 230 TO 270 DEG. C. AND 270 DEG. C. TO TAR

It must be borne in mind that the original oil which was cracked boiled between 250 and 350 deg. C., and was not attacked at all by sulphuric acid. Decomposition by heat produced low boiling fractions and changed the original fraction. This amount of decomposition was proportional to the temperature employed.

Fig. 1 brings out the decomposition to low and high boiling unsaturated hydrocarbons. The data should be divided into two parts, (a) the per cent of unsaturated compounds in the cuts up to 150 deg. C., and (b) the per cent of unsaturated hydrocarbons in the cuts from 170 deg. C. to tar. Each set has its characteristics. In the cut below 150 deg. C., the per cent of unsaturation reached a maximum at 600 deg. C. in all three cases, and then decreased to practically zero at 800 deg. C. In the cuts above 150 deg. C., the amount of olefins and similar compounds attacked by sulphuric acid increased with temperature. The determinations could not be made at the two upper temperatures 750 and 800 deg. C. as these cuts consist almost entirely of the solid aromatics, naphthalene and anthracene. It is considered that a similar maximum would have been obtained provided these could have been made, and that the unsaturation would have decreased at 800 deg. C.

These data may be used to show the effect of temperature on the formation of unsaturated compounds such as olefins, and more especially the course of the cracking reaction. The original high boiling oil on thermolization splits to lower boiling fractions containing paraffins, naphthenes, olefins and aromatics with the production of the latter depending on the conditions. In the low boiling fractions at the low temperatures, one only expects to find paraffins, naphthenes and unsaturated compounds. From the data, it appears that the

TABLE 1—PERCENT OF UNSATURATED COMPOUNDS IN THE DISTILLATION CUTS

Temp. (degrees C).....	450	500	550	600	650	700	750	800
Per Cent Unsatd. Cmpds.								
0 to 95	36	40	51	50	39	29	19	5
95 to 120	38	39	33	21	18	7	4	
120 to 150	20	28	35	52	29	33	10	
170 to 230			11	15	17	20		
230 to 270	1	4	6	8	10	16		
270 to tar	1	2	2	5	9	20		

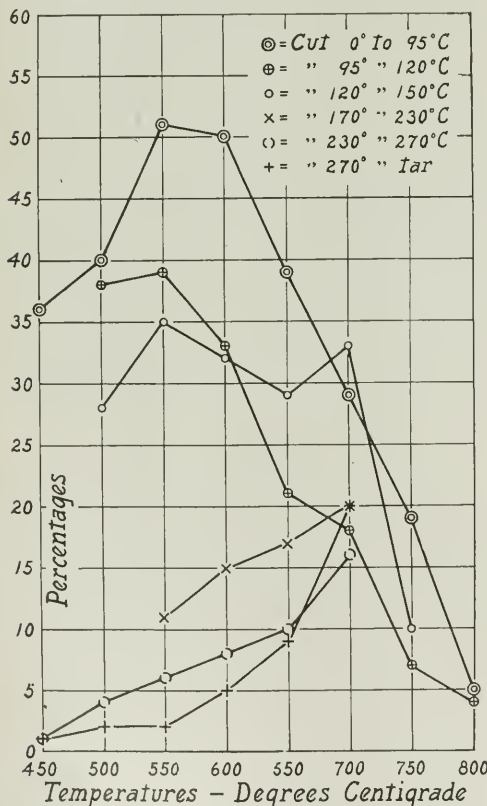


FIG. 1—PER CENT OF UNSATURATED COMPOUNDS IN DISTILLATION CUTS TO 95 DEG. C., 95 DEG. TO 120 DEG. C., 120 DEG. TO 150 DEG. C., 170 DEG. TO 230 DEG. C., 230 DEG. TO 270 DEG. C., 270 DEG. TO TAR

amounts of saturated compounds such as paraffins and naphthenes at 450 and 500 deg. C. predominate in the cut to 95, and likewise in the other two low boiling cuts. Increasing the temperature of the reaction increased the percentage of olefins in each cut. This was accompanied by increased formation of aromatic compounds¹⁰, and hence the paraffin and naphthene content must have decreased. At the higher temperatures, olefins and aliphatic saturation decreased, and aromatic compounds predominated in each cut.

The course of the reaction with temperature of the decomposition to low-boiling products may be represented by

High-boiling paraffins →
 Low-boiling paraffins →
 Low-boiling unsaturated hydrocarbons →
 Low-boiling aromatics.

Besides cracking the starting oil to low-boiling fraction, the reaction has also changed the character of the oil, and as the heat effect increases the amount of unsaturation increases, although it is not so large as was found in the lower boiling fractions. These facts are brought out from the degree of unsaturation in the high-boiling fractions, 170 deg. C. to tar. While the data do not show, it is to be expected that this formation would also reach a maximum and then decrease with the resulting formation entirely of naphthalene and anthracene in these cuts. The change with temperature on the character and composition of the high-boiling cuts may be expressed as

High-boiling paraffins →
 High-boiling unsaturated compounds →
 High-boiling aromatics.

B. THE EFFECT OF TEMPERATURE ON THE PERCENTAGE OF UNSATURATED COMPOUNDS IN THE GASOLINE CUT TO 150 DEG. C.

The total percentage of the unsaturated compounds in the gasoline cut was found by combining the percentages in the cuts which made up the fraction to 95 deg. C., 95 to 120 deg. C., 120 to 150 deg. C. For 450 and 500 deg. C. an estimation had to be made, since values were not obtained for the cut 95 deg. to 120 deg. C. at 450 deg. C., and 120 to 150 deg. C. at 800 deg. C. The results are similar to these in the distillation cuts which make up the fraction. The unsaturation, represented by 28.0 per cent at 450 deg. C., reached a maximum of 44.0 per cent at 550 deg. C., and declined to practically zero at 800 deg. C., the value being only 5.0 per cent.

Aside from bringing out the successive steps of the reaction resulting in the formation of the lower boiling hydrocarbons, the data are interesting in their relation to the making of gasoline by cracking of petroleum at atmospheric pressure. From the amount of unsaturation formed, it would not be advisable to crack an oil similar to the one employed in these experiments for gasoline, due to the high degree of unsaturation in the gasoline obtained. The refining losses, represented by the percentage of unsaturated compounds, would be excessively heavy, and enough to make a commercial operation prohibitive at atmospheric pressure. Although at higher temperatures the amount is small, it is due to the large percentage of aromatic compounds, benzene, toluene and xylenes, which have been formed, and which would not be used for gasoline at the present time.

If the effect of temperature in the cracking of oil in the gas phase may be compared to the effect of pressure in the cracking in the liquid gas phase, it would appear that the data from the Burton process and the results

obtained by Brooks¹¹ are similar to those found in the present research. The decrease in unsaturated products in which increased pressure found by them corresponds to the decreased formation with increased temperature in the present case after the maximum has been reached. There arises the interesting possibility that increased pressure in the liquid gas reaction, besides cutting down the olefin formation, produced aromatic compounds such as benzene, toluene and xylenes in the gasoline cut. There are no data to be had regarding this from the Burton process. Brooks, however, states that benzene, toluene and xylene were produced by distilling Oklahoma "reduced" oil under 100-lb. pressure, the same conditions which gave the minimum refining loss in the gasoline produced. This seems to bear out the assumption that decrease in olefin formation with increased presence is accompanied by increase of aromatics.

Some chemists may attribute the decrease as due to the polymerization of the olefins to naphthenes, as has been shown by Engler¹². On the other hand, naphthenes decompose very readily to aromatic compounds by dehydrogenation, a fact which has been shown by Zelinsky¹³ and others. The decrease in olefin formation may then be accounted for in two ways, which in both cases give the same end products: polymerization of the olefins to naphthenes, which in turn go to aromatics; polymerization of the olefins directly to aromatics.

¹⁰ Ber. 42, 4610 (1909).

¹¹ Ber. 44, 3121 (1911).

¹² Loc. Cit.

TABLE 2—PER CENT OF UNSATURATED COMPOUNDS IN THE GASOLINE CUT, 0 TO 150

Temp. (degrees C.)	450	500	550	600	650	700	750	800
Per cent unstd. cmprds...	28	36	44	41	33	25	15	5

* Estimated

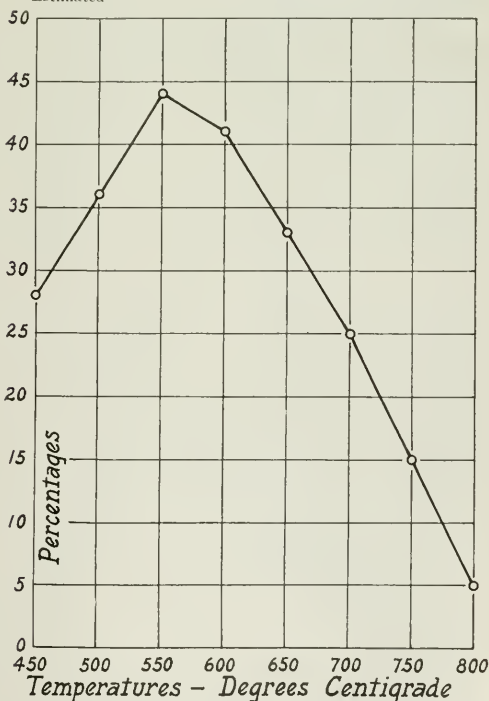


FIG. 2—PER CENT OF UNSATURATED COMPOUNDS IN THE GASOLINE CUTS TO 150 DEG. C.

¹⁰ Loc. Cit.

¹¹ Loc. Cit.

It is difficult to interpret the general statement of Hall" that high temperatures make for high unsaturation, unless the general conditions of the cracking corresponding to those at 450 deg. C., beyond which point for 100 deg. saturation increases with temperature. Even under pressure, temperature decreases the olefin formation.

C. THE EFFECT OF TEMPERATURE ON THE UNSATURATED COMPOUNDS IN THE CRACKED OIL

Another combination gave the percentage of unsaturated compounds in the cracked oil, the data being given by distillation cuts.

As a general rule, the lower temperatures produced a cracked oil which contained the largest per cent of olefins in the lower boiling cuts. Moderately high temperatures resulted in cracked oils containing unsaturated compounds distributed through all cuts evenly. The highest temperatures gave but little in the lower boiling cuts, with indications that the same would be true of the higher boiling ones. It is regretted that data could not be obtained for these. It appears then that the cracked oil obtained by the thermal decomposi-

tion of a paraffin oil contains olefins, the amounts of which are governed by the temperature of the reaction. The formation with increase of temperature reaches a maximum, and then decreases to practically zero. Theoretically this is possible. At the higher temperatures, naphthalene and anthracene form the greater portion of the oil in addition to the pitch. These compounds are much more stable than any olefins known. And with the tendency of the reaction to produce aromatic compounds, it is not to be expected that there will be very much unsaturated formation in the cracked oils produced by the high temperatures, 750 and 800 deg. C.

Conclusions

From the experimental data it is possible to draw the following conclusions:

1. Unsaturated compounds are found in the recovered oils obtained by the cracking of a gas oil, boiling between 250 and 350 deg. C., and derived from Pennsylvania crude petroleum at atmospheric pressure, and at temperatures 450, 500, 550, 600, 650, 700, 750 and 800 deg. C.
2. With the temperature range employed, the unsaturation reaches a maximum in the lower boiling distillation cuts to 95 deg., 95 to 120 deg. C. and 120 to 150 deg. C.
3. In the higher boiling distillation cuts, the per cent of unsaturation increased with increase of temperature as far as data was obtained, with indications that a decrease would have been obtained at higher temperatures.
4. In the gasoline cuts, to 150 deg. C., the unsaturation reached a maximum and declined with increase of temperature.
5. In the cracked oils obtained, the total unsaturated formation increased with temperature with indications again that a decrease would have been found at the higher temperatures.
6. The change in the composition of the lower boiling fractions of the cracked oils with increase of temperature may be represented by low-boiling paraffins to low-boiling olefins to low-boiling aromatics.
7. The change in composition of the higher boiling fractions may be expressed with increase of temperature as follows: High-boiling paraffins to high-boiling olefins to high-boiling aromatics.

Pittsburgh Division, Aetna Chemical Co., Pittsburgh, Pa.

Announcement of Special Lectures at College of City of New York

The Department of Chemistry of the College of the City of New York, Dr. Chas. Baskerville, director, announces a series of very interesting spring lectures to be given at 3 p. m. at the college on the following dates.

March 10—Food control in New York City (illustrated), by LUCIUS P. BROWN, director Bureau of Food and Drugs, Department of Health, New York City.

March 17—The Extraction of Radium from Its Ores (moving pictures), by Dr. CHAS. L. PARSONS, U. S. Bureau of Mines.

April 7—Chemical Control of Medical Supplies Purchased for the U. S. Army, by Lieut. D. W. FETTEROLF, U. S. Army.

April 14—Science in the Humanities, by ELWOOD HENDRICK.

May 5—The Emancipation of American Chemical Industries (moving pictures), by Dr. THOS. H. NORTON, U. S. Department of Commerce.

May 12—Food Poison (illustrated), by JAMES P. ATKINSON, Department of Health, New York City.

TABLE 3—PER CENT OF UNSATURATED COMPOUNDS IN THE CRACKED OIL.

Temp. (degrees C).....	450	500	550	600	650	700	750	800
Per Cent								
Unsat. Compds.								
0 to 95	0.3	1.1	3.2	5.6	5.3	5.7	4.3	1.2
95 to 120	0.6	1.3	2.0	2.1	1.8	0.6	0.3	...
120 to 150	0.1	0.2	1.1	1.7	1.9	3.1	0.7	...
150 to 170	...	...	0.3	1.0	1.3	1.9	...	...
170 to 230	...	...	0.8	1.8	2.0	1.3	2.3	...
230 to 270	...	...	0.2	1.0	1.6	2.6	3.6	...
270 to tar	0.7	1.2	1.0	1.6	2.6	3.6	...	...

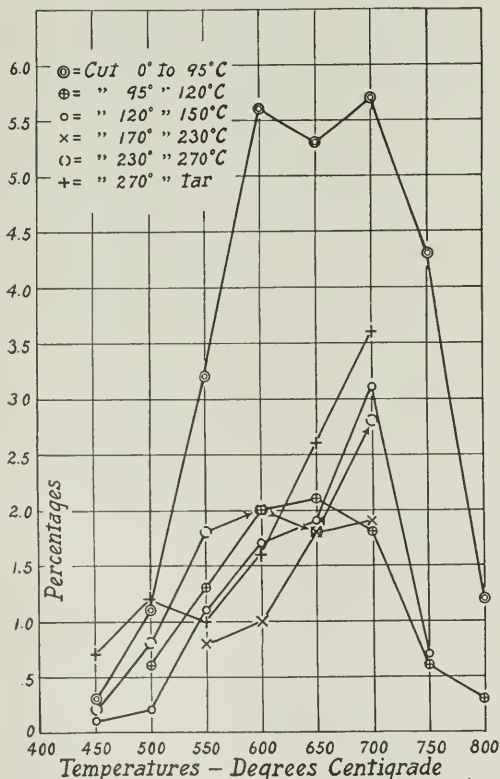


FIG. 3—PER CENT OF UNSATURATED COMPOUNDS IN THE CRACKED OIL BY DISTILLATION CUTS

Universal Flotation Theory*

BY C. TERRY DURELL

It seems incredible that every one of the many flotation processes are satisfactorily explained by an all-embracing theory. How can the theory of film flotation be identical with that of froth flotation? How is the theory of the Cattermole the same as that of the Callow? Thirty years ago Carrie J. Everson of Chicago described flotation as well as it can be described to-day, and it is quite evident from this description that thirty years ago a test might have been made for any of the many present-day processes using oil.

One theory will explain all processes of flotation if the essential element be the same in all cases. A process of elimination applied to each method of flotation will leave at least one essential element. This proved, there then follows the corollary that a theory that does not explain all processes of flotation satisfactorily is worse than useless as it is sure to confuse a subject already kept long in darkness by complicated litigation. Never before has litigation so retarded a science by smothering it in a cloud of secrecy. It is to be regretted that this condition has been brought about by some prominent engineers attempting to gain a world-wide control of all processes of flotation after the basic patents had expired.

The essential elements of flotation can be arrived at in two ways: (1) Investigation of conditions under which different minerals float; and (2) investigation of all different processes. In Australia, the home of flotation, more flotation experiments have been carried out than in any other country. This statement will not hold true for long judging from the present rate of advance in this country.

Kenneth A. Mickle's experiments published in the Proceedings of the Royal Society of Victoria¹ furnish the most complete record of systematic research to learn the reasons for flotation. These experiments were carried on with different metals and minerals in the laboratory and subject to the conditions met with in the several flotation processes. He tried them with water, oil, acid and alkali; hot and cold; at atmospheric and reduced pressure and in various combinations. Many of his experiments I have confirmed at the School of Mines. His experiments show that minerals at the surface or in the interior of liquids float or tend to float due to:

1. Liberation of gas contained in the liquid either by reduction of pressure or heat;
2. Generation of gas in the liquid by means of acid; or
3. Supersaturation of the liquid with gas.

He shows that minerals absorb (occlude) gas to a degree not previously suspected and that the effect of this occluded gas is that:

1. Particles are not wholly wetted by immersion in water;
2. Particles tend to float when sprinkled on a liquid surface;
3. Particles collect bubbles when heat or vacuum is applied; and
4. Particles collect bubbles evolved from a gas saturated solution.

The Swinburne and Rudorf² experiments show that "It seems necessary that the gas should be produced at the surface of the particles themselves." Many other references might be cited to show that the whole sub-

ject of flotation depends upon gas occlusion by the minerals to be floated.

As was to have been expected, Mickle showed the gas held by flotation concentrates consists almost entirely of nitrogen, oxygen and carbon dioxide. That is to say, the occluded gas was from the atmosphere.

These experiments have thus eliminated oil, acid, alkali, heat, vacuum, saturated gas solutions and the like as being essential elements of flotation. The conclusion that necessarily follows is that flotation depends on the fact that, due to the occluded gas of the mineral particles, they become entangled or caught by the surface film of: (1) the free surface of the liquid; or (2) the surface of a gas bubble; (a) above the surface or (b) under the surface.

It is well now to classify and investigate the different processes to see if a similar system of elimination will give the same results as this obtained from laboratory experiments.

Surface Tension Flotation

One of the oldest types of flotation is that which the prospector, in panning, tries to guard against. How easy it is to drain the water from the trail of fine gold in the pan and then pick it up on the surface of the water! Every vanner-man can testify as to the richness of concentrate from the settling boxes back under the machine behind the main concentrate box. This is the concentrate that dries as the belt travels down over the end of the vanner and floats on the surface as the belt dips into the water in the concentrate box. Hezekiah Bradford in his patent No. 345,951, in 1885, reverses this process by using a belt to remove the floating concentrate. It was nearly twenty years later (1904) that Macquisten used a spiral in a tube to lift and expose the pulp to the air so the metallic particles would float on the surface of the water in the tube. This was a commercial success, though oil is now used to aid the process. Henry E. Wood's machine, patented March 21, 1911 (No. 987,209), feeds dry ore gently onto the surface of water so that the metallic particles float over a lip and are saved. All of these cases come under what may be termed "surface tension flotation." Evidently the only essential feature is that the particles to be floated be exposed to air. That is, there must be a chance for gas occlusion. The selective action, which causes the metallic particles to float while the gangue particles sink, will be taken up later.

Bulk Oil Flotation

How "the virgins drew up gold by means of feathers daubed in pitch" is told by Herodotus. Thus that pitch, oil, grease and the like adhere to metallic particles with greater force than does water has long been known. This fact was first recognized in a patent (No. 483, British) to William Haynes in 1860. Under the Elmore patents of 1898 and 1901, bulk oil flotation was put on a commercial basis, although the many plants built in different parts of the world were doomed to failure because of the great quantities of oil necessary. Excessive oil is necessary, due to the little difference in specific gravity between oil and water as compared to the greater difference in specific gravity between water and the metallic concentrate. As no acid was at first used by the Elmore process, it is not an essential element to flotation.

The Cattermole patent in 1903 improves upon this by using less oil in what was known as the oil granule process. These granules were then removed in various ways either from the bottom of the container or driven to the surface by an upward current of water or gas. This was the forerunner of the present froth processes, but the only plant built was a complete failure. This

*Excerpt from Colorado School of Mines Magazine, February, 1916.

¹Vol. 23 and 24, Part 2, 1911. Abstracted in Eng. and Min. Jour., Aug. 12, 1911, and July 13, 1912.

²Faraday Society paper read Dec. 12, 1905. Abstracted Eng. and Min. Jour., February 10, 1906.

was to treat 400 tons daily at the Central Mine, Australia. Everyone who has made a froth flotation test has, probably, at some time, added too much oil and seen these granules resting above the pulp at the bottom of the vessel. Some may rise to the surface of the liquid and drop back again. In the Cattermole process, soap and acid were used, but a test, as above, shows that granules will form with oil only, so these two things are not essential elements. The only bulk oil flotation plant that I examined was at the Lake View Mine, Kalgoorlie, Australia. It, like all others, was a failure so I was not able to determine if gas occlusion by the metallic particles is the essential element to the process. From the very nature of the process, oil of course is an essential element. Mickle's experiments showed that mineral particles deprived of occluded gas do not, as a rule, become coated with oil in the presence of water. The selective action necessary for this flotation will be taken up later.

Froth Flotation

In taking up these processes in detail to eliminate all but essential elements to flotation, such questions as air froth or oil froth, selective or preferential flotation, and the like will not be discussed. These things as well as the forces, adhesion, electricity, cohesion, surface tension, etc., will be taken up under other headings later. About four years ago I made a trip to Australia and studied these processes quite carefully at the largest plants then in the world working four distinctly different methods. Since then I have seen several plants operating in this country but with only one different method or machine—the Callow.

Delprat Type.—The Delprat and Potter processes were developed independently at the same time, patented in 1902, and are practically the same. This was the first commercially successful froth flotation. It has since proved unfortunate for Minerals Separation that the Fremont patent in the same year was only taken out in Italy and England. For this reason it was necessarily suppressed by the purchasers. Also processes where gas is generated by electrolysis like the Fields come under this heading.

As G. D. Delprat was general manager of the Proprietary Company at Broken Hill, his process was naturally used there. About 1000 tons were being treated daily when I studied the flotation process at this property. A "push feeder" delivered 700 pounds of ore per minute to a single spitzkasten where flotation took place without agitation except that of the upward current of hot acid solution being added at the bottom. By heating the solution with superheated steam, it was intended to work with a solution as near 80 deg. C., the critical temperature for flotation, as possible. The working solution temperature, however, was below 70 deg. C. The quick action and simplicity of the process was most pronounced. A marketable zinc concentrate was being produced with high recovery without retreating it or the tailing. The essential elements may be summed up as follows: gas, acid and heat in addition to the ore and water. The acid attacking the carbonates in the ore produced the bubbles in addition to the selective action which will be taken up under a separate heading. This gas made the bubbles for the froth, as no air was taken into the solution in any way except the little that might come in with the ore. None could come in with the solution as no jet or nozzle was used above the surface of the liquid, which would have carried air in, as will afterward be described. This solution was brought in at the bottom of the spitzkasten and, being hot, could contain but little dissolved air. Since heat was necessary, its only function was to expel occluded air from

the mineral particles the same as from liquid in accordance with the law of Henry.

Vacuum Type.—The Elmore vacuum machines were being used at the Broken Hill, British plant, although they had been thrown out from several other plants there. This was not due to unsuccessful operation but to litigation. No more than the following essential elements are necessary for the operation of the Elmore, the only successful vacuum process: vacuum (to liberate the air to form bubbles), acid, oil and alkali. Cast iron machines are used so lime is required to neutralize the pulp before it goes to the vacuum machines. The acid of course is not to generate bubbles as in the Delprat process. Therefore, the acid creates the selective action the same as in the Delprat process. In accordance with Henry's law, gas or air is liberated from the pulp by reduction of pressure to form the froth. As will be shown later, these bubbles must necessarily form on mineral particles as nuclei. The bubbles burst very readily in the Delprat process, but there is such an ebullition that any metallic particles thus dropped are caught by the bubbles below. There is no chance for this with the Elmore so the bubbles must necessarily be more persistent. In the Delprat, the bubbles are armored with the metallic particles. To make them more persistent in the Elmore, oil, in addition to the metallic particles, is used to coat them. This toughening of the froth with oil will be taken up under a separate heading.

Minerals Separation Type.—Under this heading may be grouped all processes or machines using rapidly revolving paddles or stirrers to beat air into the solution. This method of forcing air into solution beyond the point of saturation was known long before our grandmothers used it to beat eggs or whip cream. It matters not whether air be beaten by being admitted to the suction of a centrifugal pump or to the periphery under pressure or beaten in by the propeller on the vertical shaft of a mineral separation or other machine. The essential elements can be eliminated as follows: air (beaten in to supersaturation), acid, oil and heat. What is the difference whether bubbles be formed from air coming out from a supersaturated solution or from a solution subjected to vacuum? Bubbles will form on mineral particles as nuclei in either case. The acid here of course acts as in the former case. Since heat is not always used, its only function can be to assist in expelling the air from the mineral particles. The froth from these machines is the most persistent. This is due to the greater amount of slime and the better agitation to oil-coat the metallic particles. Like butter in a churn, these fine metallic particles are coagulated by the violent agitation. The mineral particles are so well oiled that an exceedingly coherent armor for the bubbles is produced. The oil films of these bubbles are extremely thin like those of other processes. Iridescent colors indicate this. The surface tension effect of the oil is added to that of the water for further toughening the bubbles.

DeBavay Process.—This, at first, appears to be a purely surface tension process. As originally patented by DeBavay, it probably was, but, as now used by the Amalgamated Zinc, Ltd., of Broken Hill, it even has the bubbles, although all the large ones are liberated before flotation commences. The same principles apply here as in any froth flotation. The clean sand is thoroughly agitated in an acid solution, washed and then again agitated in steel tanks with water to which a fixed amount of an oil mixture (mostly kerosene) has been added. The agitators in these tanks are like ship propellers and as large. This gives thorough oiling to the particles. A montejus delivers the pulp to the top

series of four each DeBavay cones. The pulp is, therefore, surcharged with air due to this air pressure, since the air dissolved by the water varies directly as the pressure. Norris has patented (No. 864,856) the idea of thus surcharging a liquid with gas, but he delivers the surcharged liquid beneath the surface of the pulp mixture. The Callow machine also uses this principle except that the air pressure is exerted on the bottom of the liquid instead of on the top as with a montejus. There are no bubbles or froth because the pulp mixture from the montejus is turned on to the apex of the cones and spreads out, flowing down the steeply inclined surfaces. The essential elements to this process are: gas (in the form of air), acid and oil. These are the same as with preceding processes. Although there is no froth, air is here the prime requisite while the acid creates the selective action. The metallic particles are so well oiled they are not easily wetted by the water while their air films and minute attached bubbles bodily lift them to the surface of the water if, by chance, they go in under instead of on the surface when they strike the water at the periphery of the cones. In a laboratory test, the metallic particles seem to jump from the bottom of a beaker to the surface of the liquid.

Callow Type.—This includes all froth flotation processes depending on the supersaturation of the liquid by air pressure in accordance with the law of Henry. The DeBavay process was taken up previous to this as it is the connecting link between this and Mineral Separation type. It (DeBavay) uses violent agitation which beats in air and also direct air pressure which supersaturates the pulp mass.

This supersaturation is caused, according to the Norris patent, by subjecting the liquid to an air pressure of several atmospheres. In the Callow machine, it is "a hydraulic pressure varying from 15 to 40 inches" that causes the liquid at the bottom of the box to absorb air beyond the saturation point of the surface liquid at atmospheric pressure. If too much air is blown into a Callow machine, the effect is the same as the air in the pachuca tank—agitation.

The bubbles composing the froth are derived from that air which was first absorbed and afterward liberated on a mineral particle as a nucleus in the same way that air, beaten into solution in a Mineral Separation machine, supersaturates the liquid and comes out in the form of bubbles. A jet of air turned into liquid pulp produces bubbles which effect no mineral attachment. They pass through the pulp as do those from excess air in the Callow cell. The essential elements for the Callow type may be picked out as follows: air (from supersaturation of the liquid), oil and acid or alkali. The oil, as shown above, aids in making a more persistent froth. It is mixed with the pulp previous to entering the machine. The acid or alkali is to form an electrolyte for selective action.

Liquid Jet Type.—Heretofore only two ways of getting air into solution have been taken advantage of to aid flotation. These, as mentioned above, are: (1) beating it in as is done in Mineral Separation type; and (2) surcharging the liquid with gas as is done in the Callow type. While experimenting at the Colorado School of Mines some three year ago, I developed a third way which is now being patented. One of the patents has been issued.

Common occurrences of this phenomenon are seen everywhere. On drawing water into a beaker, bubbles form and rise to the surface. Where does the air come from? A muddy overflow is caused in a settling tank by allowing the mill stream to be turned down into the tank from some little distance above. Froth forms and overflows. Hydraulic air compressors and

blowers are operated on this principle by turning a stream of water down a shaft or pipe. In the same way that an air film surrounds a drop of liquid so that the drop method may be used in determinations of surface tension, so does an air cylinder enclose a liquid jet. This adhesion is so great that air is carried into the liquid to the supersaturation point and it comes out in the form of bubbles.

The model I built at the School treated ore at the rate of twenty-five pounds an hour working in an acid solution with oil fed to the first cone. This type of machine produces either a scum float like DeBavay's or a thick persistent froth with well armored bubbles. The essential elements may be noted as follows: air (brought in by the liquid jets), oil and acid, or alkali.

Having classified flotation into that of (1) Surface Tension, (2) Bulk Oil and (3) Froth and subdivided Froth Flotation into the different types of (a) Delprat, (b) Vacuum, (c) Mineral Separation, (d) Callow, and (e) Liquid Jet, there are found only these few essential elements as follows: air or other gas, acid, heat, vacuum, oil and alkali. These only are necessary in addition to the liquid and the ore. It is possible to still further eliminate.

Essential Elements

Cold solutions were seen to be used with some processes. Therefore heat is not an essential element to flotation. Vacuum is used in the one type to produce the gas so it is not essential to flotation. Oil is not always used in froth flotation so it is not an essential element to any except bulk oil flotation. This fact is also shown by the new process of Louis A. Wood. An alkali is used in one case to neutralize the excess acid and in others in place of an acid. Either an acid or an alkaline solution will do and, from the amounts used in mill solution, it is seen that extremely dilute solutions are effective. That is, complete ionization exists and the effect is that of an electrolyte. By this process of elimination there is left the essential elements as follows: air for surface tension flotation; oil for bulk oil flotation; and gas and an electrolyte for froth flotation.

It is seen that the gas, to form bubbles in froth flotation, can be generated chemically or electrolytically within the pulp mass or it can be (1) beaten in with stirrers, (2) forced in by pressure (that of the atmosphere or greater), or (3) carried in by jets. Something more than mere bubbles of gas within the pulp mass is necessary to make froth flotation effective.

The mineral particles must either be attached to the bubbles or the bubbles must be attached to the mineral particles. It amounts to the same thing whether the bubble be attached to the solid or the solid attached to the bubble. Since a bubble carries with it a surface film of liquid, the mineral particle must be caught by this surface film in froth flotation or caught by the free surface of the liquid in surface tension flotation. The necessary conclusion then is that some inherent property of the mineral particle itself is the cause of its resting on the surface of the liquid in the one case or on the surface of the bubble in the other. If it were possible to attach a mineral particle to a bubble already formed by some physical, chemical or electrical force, then it might be possible that surface tension flotation and froth flotation are in no way related, and that bubble attachment is in no way dependent upon some property of the particle itself. It is a well known fact, however, that no such attachment can take place to bubbles that are already formed.

A stream of compressed air turned into a pulp mass in a perfect float condition can not effect flotation, as

is well known by every one who has tried it. The bubbles not only rebound from one another but the mineral particles show no tendency to adhere and the bubbles come to the surface without the mineral particles. This is due to the surface film, which phenomenon will be taken up later, when it will be shown that there can be no adhesion between this liquid film and the mineral particle, be it either wetted with oil or water. There is no reason for any chemical affinity.

Electrical Theory Insufficient

In an electrical field, it is possible for bubbles to be electro-negatively or electro-positively charged. There is no reason why these charges might not be reversed at will by varying the field. Also it is a well known fact that mineral particles can be electrically charged and this is taken advantage of in electrostatic concentration, Cottrell dust precipitation, clay separation, etc. It is also shown in colloidal work that, under the same condition, some minerals are negatively charged while others have an opposite charge. It is upon these facts that electrical theories of flotation are based. Assume that the particles of metals, sulphides, tellurides, arsenides and the like "have charges of one polarity (positive), and that non-floatable particles have charges of the opposite polarity (negative)," and also that the bubbles are negatively charged. Witness, then, the metallic particles jumping for and clinging to the bubbles. A beautiful theory if it were true and would explain all connected with flotation.

In the first place, flotation is not dependent upon an electrical field as is electrostatic concentration, dust precipitation, Botho Schwerin's electro-osmotic process and others. It would also be possible to attach mineral particles to bubbles already formed by the assumption of an electrical theory. So far, these electrical theories have considered oil as an essential element to flotation, which, as shown above, is not the fact. If a slight change in the strength of the electrolyte will change the polarity of quartz, calcite and the like so as to cause them to sink, when before they were floating, why will it not also change the polarity of some metallic particles so as to create a preferential flotation? No. It is far better to make a theory conformable to the facts than to try to ignore and twist facts to conform to some of the present electrical theories. Since there is no known way to attach mineral particles to bubbles already formed, bubble attachment depends directly upon some property of the particle itself. This property must then be the same for particles floating in either a surface tension or a frothing machine. As shown by Mickle's experiments, this must be due to gas occlusion.

Why is it then that no solid can be floated unless it contains occluded gas? A particle once wetted with the flotation liquid tends to sink as there is no surface tension effect tending to float it. Water is always used as the flotation liquid as it is the cheapest and has the greatest surface tension of all liquids except mercury. If all gases be driven from a solid, water will enter the pores and adhere to its surface. No surface tension effect can be then exhibited towards it for the reason that it is then as part of the water. Thus a force of adhesion predominating, flotation can not take place. This truth is not so readily seen when the particle is below the surface of the water and an attempt is made to float it by means of a bubble. The surface tension of the liquid film surrounding a gas bubble is much greater than the adhesive force of the gas for a solid. The gas is, in this way, firmly held within the enclosing liquid film and attachment between it and a solid cannot take place. As has been shown above, it

is only the gas that comes into being within the pulp mass that is of any value in flotation. In other words, this nascent gas is attracted by the gas at the surface of the solid. A cohesive force exists between the molecules of the gas at the surface of the solid and those in the immediately surrounding liquid so that the solid becomes a nucleus for the formation of a bubble from the nascent gas of the liquid. As shown above, there are three mechanical ways of forcing air or a gas into solution. Also there are three methods of expelling it: (1) supersaturation so that the excess gas is driven out; (2) heating to increase the volume and drive some out; and (3) reduction of pressure.

Role of Occluded Gases

The same cause that tends to supersaturate a liquid with gas will evidently tend to supersaturate a solid with this same gas if this solid be within the liquid. Also the dissolved gas will evidently be expelled from both the liquid and a solid within it by the same force—one of the above. Due to adhesion, the gas, as it is expelled, tends to condense on the solid or increase the amount of absorbed gas. Lest confusion arise, it may be stated that "absorb" is here used in the sense of being one of the three ways that solids hold gases. With sufficient condensation, a bubble will form on the surface of the solid from these molecules as they collect.

As a logical sequence from the above reasoning, solids with high occlusive power for gases should have a greater tendency to float. Hezekiah Bradford was the first to recognize this fact.³ "These floating particles appear to possess some peculiar qualities which repel water from their surfaces, especially when the particles are exposed, even momentarily, to atmospheric air." It is only necessary to look into the subject of ore deposition to learn the reason why metallic particles occlude gas more readily than other minerals. Chemical affinity assists in this occlusion of air and carbon dioxide, which eventually change the sulphides and like ores into sulphates, carbonates, oxides, etc. This greater power of occlusion is a cause of selective flotation.

Selective flotation is here used as a general term in contradistinction to preferential flotation, an accepted term to designate the separation of minerals that ordinarily float together. Horwood accomplishes this by a roast that oxidizes some sulphides and not others. The same effect is accomplished by others by coating the sulphides not desired in the concentrate. Leslie Bradford uses a reducing gas to accomplish this result.

By the aid of the microscope, Hebron, an associate of Carrie J. Everson, discovered that the desirable minerals, to be saved by concentration, have larger pores and surfaces than equal sized gangue particles. This gives greater chance for gas occlusion. Oil and like substances are usually but slightly soluble in water. The reverse is also true. There is little adhesion between water and a surface wetted with oil, or oil and a surface wetted with water. Oil, due to its property of capillary attraction, can readily enter the pores of solids not filled with water. Therefore, most metals, sulphides and the like containing occluded air, are capable of absorbing more oil due to their larger pores and surfaces. With sufficient oil thus attached, agglomeration or bulk oil flotation takes place.

By this process of elimination, the same conclusion is reached as that demonstrated by Mickle's experiments. Gas is the necessary element for surface tension, bulk oil and froth flotation methods and this must be occluded gas. Nascent gas and an electrolyte are also essential elements for froth flotation.

³U. S. Pat. No. 345,951. 1885.

Function of Electrolytes

What is the function of the electrolyte? As has been shown, an acid or an alkali creates the selective action in froth flotation. How? By its ability to vary the contact angle between the surface of the mineral particle and the liquid film on either a bubble of measurable radius or a horizontal liquid surface of infinite radius. Dr. Young showed the constancy of contact angles. H. Livingston Sulman, investigating figures for contact angles found "discrepant readings" due to "existence of a variable range of the contact angle." C. G. Lamb termed this angular difference "the angle of hysteresis." Speaking of this, Mr. Sulman says: "Whereas the angular hysteresis of silica in plain water may exceed 30 deg., thus indicating the substance to have a definite power to occlude gas and to float, it drops from 4 deg. to nil in water acidulated with sulphuric acid."

The occluded gas can be driven out from a solid in the same way that it can be driven from a liquid. This gas of the solid particles will cause them to become nuclei for the formation of bubbles from the gas "coming into being" from the liquid and, as the bubbles grow, the particles are lifted or floated. Since there is more occluded gas in the metallic particles, all that is necessary to create the selective action of flotation is to drive out a considerable portion of the occluded gas from all particles. There then will be insufficient gas remaining with the gangue particles to cause them to act as nuclei upon which to grow bubbles. The metallic particles still having occluded gas are then floated while the gangue particles sink.

As above shown, this selective effect is produced in extremely dilute solutions. An electrolyte produces it, but how? It was also shown that some force is required to expel occluded gas. No outside force such as pressure or heat is the cause. Therefore it is an internal one that drives this occluded gas from the mineral particles. The ions of the electrolyte displace the equilibrium and the force that causes the gas occlusion is, at least partially, neutralized so that the tendency of the gas is then to diffuse throughout the liquid instead of remaining in the solid.

Effect of Osmosis

A parallel case in physics is osmosis. The function of the electrolyte, therefore, is to create osmotic pressure. The septum is the surface of the mineral particle. Ions of the electrolyte enter the solid while those of the gas leave. This action continues to the eutectic point and bubbles form on the metallic particles, as described above. Greater delicacy of manipulation is obtained with an alkali. Further advancement along this line means that selective action can be created between sulphates, carbonates, etc., and gangue minerals. Also that, by means of a variation of the electrolyte, preferential flotation can be effected and different metals can be separated.

Increased strength of the electrolyte will sometimes "kill" the float; or, in other words, increased osmotic pressure drives the air from the metallic particles leaving them in the same condition as those of the gangue. This effect is not to be confused with an entirely different phenomenon which produces the same effect. Colloidal impurities like tannin, saponin, etc., or volatile oils and the like destroy bubbles by reducing the surface tension to the extent that the gas pressure from within bursts them. This weakening of the surface tension by a colloid is thus seen to be entirely different from the strengthening of osmotic pressure by a crystalline although the result is practically the same—no froth.

In studying this selective action, it is difficult to explain the motive power of osmosis, as present authorities do not agree. According to the Van't Hoff school it is the kinetic energy of the dissolved molecules obeying the laws governing gas pressure. It is the impact of these molecules against the walls of the semi-permeable membrane. On the other hand, Kahlenberg shows it to be the force of chemical affinity, while Professor Traube proves it is an "interfacial pressure obtained by subtracting the surface tension of one fluid from the tension of the fluid into which it diffuses." Since surface tension is a cohesive force, osmosis may depend upon electromotive force because, according to both Sir Oliver Lodge³ and Fernando Sanford,⁴ the forces of chemical affinity and cohesion are electrical. This is a much mooted question for, by assuming Dr. Lupke's⁵ "Osmotic Theory of the Current of Galvanic Cells," the starting point is again reached. Fortunately the question as to the motive power of osmosis has no bearing on the result of the selective action in flotation caused by osmosis. As shown, this selective action in all three methods of flotation depends primarily upon gas occlusion by the mineral to be floated. Mickle showed that no mineral will float on the surface of hot acid solution, even if dilute. Thus an electrolyte creates a greater selective action in surface tension flotation.

This selective tendency exists in neutral solutions due to the fact, that metallic particles occlude more gas than others. In bulk oil flotation, the metallic particles have occluded more air and, hence, are more easily wetted with oil than with water. The osmotic force set up by the electrolyte in froth flotation expels occluded gas from the mineral particles. There is still left with the metallic particles sufficient gas for them to act as nuclei so that the nascent gas of the liquid may form bubbles to float them.

Just as vapor must have a nucleus upon which to form a rain drop, so the nascent gas in flotation pulp must have a nucleus upon which to form a bubble. Duhem⁶ shows that a bubble will never form where the liquid is continuous, due to the fact that its infinitely small radius would be less than the limiting radius of collapsibility. Note how the vapor bubbles of boiling water form on the bottom or sides of the vessel.

Action of Bubbles

Not only are bubbles necessary for froth, but they must be more or less persistent. The surface film that encloses the bubble as it is formed in the interior of the liquid becomes a part of that bubble and, due to surface tension, remains with it throughout its passage to the surface of the liquid, in the same way that the surface film of a soap bubble remains with it throughout its passage in the air. This is easily proved by slowly blowing a colored bubble at the bottom of a large beaker of which the upper portion at least is filled with clear liquid. Due to this fact, the bubbles may have their films strengthened or toughened so they will endure for a longer time. Therefore, if the bubble be coated with some such substance as oil, the total force of surface tension is increased, due to the surface tension of the water film plus that of the oil film. Surface tension tends to decrease the size of the bubble as is well illustrated by Boys,⁷ while the expansive force of the gas enclosed tends to enlarge it. The hydrostatic head aids surface tension in maintaining the bubble in the interior of the liquid.

³Electrons by Sir Oliver Lodge, Principal the University of Birmingham. Chap. 16, Nature of Cohesion, Page 153, July, 1906.

⁴A Physical Theory of Electrification (1911), by Fernando Sanford, Prof. of Physics, Stanford University. Page 43.

⁵Elements of Electro Chemistry, by Dr. Robert Lupke. Part 3.

⁶Thermodynamics and Chemistry, by P. Duhem, 1903. Page 366.

⁷Soap Bubbles, by C. V. Boys.

^{*}Presidential address of H. Livingston Sulman. Institution of Mining and Metallurgy Transactions, 1912.

Arriving at the surface, the bubble may burst due to: (1) interior gas expansion; (2) adhesive force of the contained gas for the atmosphere; (3) evaporation of the enclosing film. Therefore an immiscible substance aids in two ways in making the bubble more persistent: (1) adding to the force of surface tension; (2) forming a film less easily evaporated. Since molecular forces are dealt with, these films approach one molecule in thickness and hence little oil is required. The colors of the bubbles also show this.

In addition to the oil film, the bubbles may be still further strengthened by an armor of metallic particles. These metallic particles containing occluded gas are, as shown above, more easily oil-coated than gangue particles. Due to cohesion, an electrical force, these particles are firmly held together and to the bubble film, which is then enclosed in a network of them just as a balloon is enclosed in a netting of rope. Bubbles thus made will endure for days and have been spoken of as "oil froth."

Oils that are good "collectors" are practically insoluble in water and form a film not easily evaporated, so make persistent bubbles. Good "frothers" are oils more or less soluble and, while they make quantities of bubbles and much froth, evaporate quickly, so that the bubbles burst more readily. Mineral particles are very easily coated with volatile oils and the bubbles are readily armored, but they burst readily, sometimes with violence. Being soluble, these oils decrease the surface tension since their surface tension is less than that of water.

Most oils aid flotation in three ways: by (1) increasing surface tension of the oil film with the additional force of surface tension of the water film; (2) decreasing adhesive force of the water for metallic particles by forming films around them; and (3) increasing cohesive force of metallic particles for each other by means of the oil film. Thus it is seen that although oil is a great aid, there can be no universal theory for flotation which considers oil necessary. By this method of elimination, it is shown that all processes and kinds of flotation can be satisfactorily explained by gas occlusion and that the bubbles for froth formation are from nascent gas.

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Coal, Coke and Limestone Efficiency in Blast Furnace Operation

BY BIRGER F. BURMAN

(Concluded from page 140)

Limestone Efficiency

Limestone is of a strong basic composition, while alumina must be considered as a distinct acid. Before limestone can act as a flux on other materials its own impurities must be satisfied by part of its own bases. Therefore the value of a limestone is dependent on the amount of its net available base.

A pure limestone contains 100 per cent carbonates, representing the maximum amount any limestone can contain. Consequently such a limestone must be considered as "100 per cent efficient" and another limestone with less carbonates as less efficient.

Phosphorus, except in very small quantities, must not be present; therefore, a limestone, even very efficient otherwise but containing comparatively much phosphorus, must be eliminated at the quarry.

Sulphur, on the other hand, may be taken care of by the furnace slag. However, it increases the cost of production. Therefore it should come within the scope of the regulating guide of an efficiency system. Under ordinary conditions the quantity of slag in the furnace

is more than sufficient to keep this sulphur in a safe solution, but when it is remembered that its presence increases the already too high amount in the coke, it is evident that it will be of advantage to keep the amount of sulphur in limestone at its minimum.

The actual weights and not the oxygen shall determine the value of each part, whether base or acid in the matter of fluxing; and for the sake of further simplicity Al_2O_3 shall be considered equal to SiO_2 as acid and MgO equal to CaO as base. Other bases present as, for instance, FeO , shall ordinarily not be included with CaO and MgO when determining the efficiency, neither shall sulphur as CaS . In other words, in order to make as little work as possible for the chemist, analyses on SiO_2 and Al_2O_3 only shall be made on every limestone shipment at the quarry and on the daily consumption at the blast furnace. The difference between 100 and the summated acid, thus found, shall be considered as summated carbonate. For instance, a limestone containing

SiO_2	6.72 per cent
Al_2O_3	4.07 per cent

Total 10.79 per cent summated acid

will therefore have $100 - 10.79 = 89.21$ per cent summated carbonate. If the slag runs with summated acid equal to summated base, the weight of useless stone must be 2 (summated acid) plus the weight of that carbonic oxide, which accompanies the base of the same weight as the summated acid. In this case the useless part of the limestone, considering CaO , CO , as flux, will therefore be $10.79 + (1.79 \times 10.79) = 30.10$ per cent, and the efficiency about 69.90 per cent.

Above calculations will be close enough for everyday use in order to simplify work in the laboratory. However, at the end of the week a complete analysis is made of an average sample of all the limestone consumed during the week. Based on this analysis a more thorough record is made. FeO as base is now included in the summated base and P_2O_5 and CaS are given due consideration.

LIMESTONE AT THE QUARRY

It is, of course, at the quarry that the quality of the limestone must be kept up or improved upon by the elimination of impurities. This can be done only by the aid of the laboratory. Analyses are made on average samples, taken on every shipment, sent to the blast furnace, and with the shipment the following report is forwarded:

REPORT ON LIMESTONE SHIPMENT NO.

Date of shipment:		
Number of cars:		
Weight of limestone (in tons of 2240 pounds):		tons.
Kind of limestone:		
Analysis: SiO_2	7.70%	
Al_2O_3	4.58%	12.28%
P		.01%
S		15%
Stone efficiency: $100 - [12.28 + (1.79 \times 12.28)] = 65.74\%$		

LIMESTONE AT THE BLAST FURNACE

There might be established such conditions at the quarry and the blast furnace that resampling and check analyzing would be unnecessary. However, that would be exceptional. It is safe to say that all limestone used at the blast furnace must be sampled and analyzed daily.

METHODS OF TAKING AVERAGE SAMPLE

All limestone used each day is sampled as usual. A certain weight of this sample, crushed and prepared, is put aside. The amount is a fixed weight per 1000 lb. of limestone used. At the end of the week the seven samples thus received are thoroughly mixed.

METHODS OF REPORTING ANALYSES

Daily form:

DAILY ANALYSIS NO. OF LIMESTONE

Used in the blast furnace No.	Date:	Tons
Weight (in tons of 2240 pounds):		
Kind of limestone:		
SiO ₂ %		
Al ₂ O ₃ %		
P %		
S %		

Weekly form:

AVERAGE ANALYSIS NO. OF LIMESTONE

Used in the blast furnace No.	during the week ending:
Daily samples used: No.	thoroughly mixed:
Weight (in tons of 2240 pounds):	Tons.
Kind of limestone:	
SiO ₂ 5.80 %	Summated acid = 9.80%
Al ₂ O ₃ 4.00 %	
CaO 46.54 %	
MgO 2.78 %	Summated base = 50.21%
FeO .89 %	Fe .69%
P ₂ O ₅ .023% P .01%	
CaS .340% S .15%	
CO ₂ 36.57 %	in combination CaO, CO ₂
CO ₂ 3.06 %	in combination, MgO, CO ₂
Total 100.003%	

NOTE:

P ₂ O ₅	equals 2.29 x P
CaS	equals 2.25 x S
CaO	from which Ca in CaS has been reduced equals 1.75 x S
CO ₂	equals 11 x CaO
CO ₂	14
	equals 1.1 MgO

RELATIVE VALUE OF LIMESTONE

As was said under coke regarding the necessity of figuring out the relative value of that material, this can also be said of limestone. Standards are necessary for comparison, and averages for some previous period, say one year, should be adopted. Figures given below are merely inserted as examples and should be modified to suit local conditions.

STANDARDS:

1. Cost of coke per ton of 2000 pounds, here assumed to be \$2.20
2. * Cost of pure available carbon (sulphur included), here assumed to be 4.701
3. Cost of limestone per ton of 2240 pounds, here assumed to be 1.10
4. Cost of slag from tapping to its disposal by the R. R., per ton of 2240 pounds, here assumed to be 0.20
5. Amount of pure fixed carbon to melt the slag = 0.22S pound per pound of slag.
6. Acids in the slag. Here assumed to be 1.
7. Actual weights and not oxygen proportions shall be considered as finding standards.
8. Al₂O₃ shall be considered as acid.
9. CaS shall be considered as neutral.
10. Analyses of coke and coke ash—here assumed (see below).
11. Maximum amount of sulphur in the slag—here assumed to be 1.40%.
12. The relative value of any limestone shall be determined by the cost per ton of 2240 pounds of pure available base.
13. It is assumed that coke ash and slag from flux go unchanged into the furnace slag.

EXAMPLE:

A certain limestone gives the following analysis:

SiO ₂ 5.80%	} 9.80% acids
Al ₂ O ₃ 4.00%	
CaO 46.54%	} 50.21% bases
MgO 2.78%	
FeO .89%	
P ₂ O ₅ .023%	P .01%
CaS .340%	S .15%
CO ₂ 39.63%	

Total 100.003%

*This is a matter of course.—See Coke Efficiency.
Going to the slag: $9.80 + 50.21 + 0.34 = 60.35$

Standard analysis of coke (wet) used:

Moisture	2.50 %	SiO ₂ 6.02 %
Vol. matter	1.50 %	Al ₂ O ₃ 3.61 %
Fixed carbon	82.52 %	CaO .666 %
Ash	12.53 %	MgO .24 %
P (remaining in the ash)	.024%	FeO 1.80 %
S (remaining in the ash)	.130%	P ₂ O ₅ .033%
S (remaining in the combustible)	.750%	CaS .293%
		Total 12.684%

Going to the slag: $12.684 - 0.055 = 12.629$

Limestone: SiO ₂ 5.80 %	Going to the slag: 5.80
Al ₂ O ₃ 4.00 %	4.00
CaO 46.54 %	46.54
MgO 2.78 %	2.78
FeO .89 %	.89
P ₂ O ₅ .023% P .01%	.34 CaS
CaS .340% S .15%	Total slag 60.35
CO ₂ 39.63 %	Bases in excess 50.21 - 9.80
Total 100.003%	Slag from impurities 60.35 - 40.41 = 19.94

Sulphur dissolving efficiency of the slag:

Slag required to keep 0.15% S in solution:

$$\frac{1.40}{100} = 0.15$$

and $y = 10.714$ parts of slag per 100 parts of limestone.

Net slag available 60.35 - 10.714 = 49.636
 Sulphur dissolving efficiency $49.636 \times 100 \div 60.35 = 82.25 \%$
 Slag efficiency = Total slag (see above) 60.35 %
 Fluxing efficiency = Bases in excess (see above) 40.41 %
 Fuel required per 100 parts of limestone:

Sulphur in coke: $0.05883 \times 0.88 = 0.05177$
 Sulphur in stone: 0.15 0.20177 S

Slag must be supplied for this sulphur.

See Coke and Limestone—Supplement—Cases II and III.

5.883 coke requires $0.05883 \times 6.924 = 0.407$ base and produces 0.05883 $\times 19.553 = 1.150$ slag
 The 0.20177 sulphur requires $0.20177 \times 24.16 = 4.875$ coke
 The 0.20177 sulphur requires $0.20177 \times 1.43 = 0.289$ base
 The 0.20177 sulphur requires $0.20177 \times 81.89 = 16.523$ slag
 The 0.20177 sulphur produces $0.20177 \times 86.61 = 17.475$ slag
 Difference between slag produced and slag required: 0.952 slag
 Total coke required 5.883 + 4.875 = 10.758 coke
 Total slag present $19.94 + 1.15 = 0.952 = 22.042$ slag
 Sulphur-free slag available 22.042 - 16.523 = 5.519 slag
 Base available $40.41 - (0.407 + 0.289) = 39.714$ slag
 Sulphur in coke 0.10758 $\times 0.88 = 0.09467$
 Sulphur in stone 0.15 0.24467 S
 Sulphur in slag $24.467 + 17.475 = 1.40\%$

One part of limestone:

requires 0.10758 parts of coke
 furnishes 0.05519 parts of sulphur-free slag
 furnishes 0.39714 parts of net available bases
 furnishes 0.22042 parts of sulphur saturated slag

COST—SULPHUR INCLUDED:

Limestone costs \$1.10 $\times 1. = 0.39714 = \$2.7698$
 Coke costs $2.20 \times 1.12 \times 0.10758 \div 0.39714 = .6675$
 Slag costs $0.20 \times 0.22042 \div 0.39714 = .1110$

Total \$3.5483

Deduct for sulphur-free slag—See Coke and Limestone—Supplement, Case I.

$80.001 \times 2240 \times 0.05519 \div 0.39714 = 80.3113$
 Net cost per ton of 2240 pounds of net available base = 3.237

Net cost per ton of 2240 pounds of limestone:

$$3.2193 \div (1 + 0.39714) = 1.279$$

COST—SULPHUR NOT INCLUDED:

One part of limestone

requires 0.05883 parts of coke
 furnishes 0.4041 - 0.00407 = 0.40 parts of net available base
 furnishes 0.1994 + 0.0115 = 0.2109 parts of slag
 Limestone costs $1.10 \times 1. = 0.40 = \2.750
 Coke costs $2.20 \times 1.12 \times 0.05883 \div 0.40 = .362$
 Slag costs $0.20 \times 0.2109 \div 0.40 = .101$

Total cost per ton of 2240 pounds of net available base \$3.123
 Total cost per ton of 2240 pounds of limestone $123 \div (1 + 0.40) = \$1.249$
 Cost due to sulphur alone, per ton of 2240 pounds of limestone (no cost for reduction included) $1.279 - 1.249 = \$0.030$

COKE AND LIMESTONE—SUPPLEMENT

As sulphur plays such an important part in the blast furnace operations, where its presence in the slag must not exceed a certain limit, more or less dependent on local conditions, great care must, of course, be taken to produce sufficient quantities of the slag, in order to keep the sulphur on hand in a safe solution. While sulphur is transferred into the blast furnace through the medium of most anything that is charged into it, it is principally coke, however, that is the source of this element. If it were not for the coke, hardly any precautions would be needed, as the slag, that would have to be made anyway, usually is more than sufficient to take care of the smaller amount present in ore and flux. For calculating the relative cost of any kind of material entering the blast furnace it will therefore be convenient to have standard figures on hand relative to the amount of coke, flux, etc., necessary to put a unit of sulphur into the slag, thereby producing a standard sulphur solution. The sulphur in question will, of course, be the surplus amount left over after the slag on hand has been satisfied.

Calculations given below are examples and must be modified to suit local conditions. Results are, however, standards and should be made up once for all to be used during a period of say one year or during the time the standard analyses of coke and limestone are in force. A standard sulphur solution must also be adopted. There will now be five different cases to consider:

Case I. Limestone, sand, or its equivalence, and coke added.

II. Net base, sand or its equivalence, and coke added.

III. Net sulphur-free slag, net base for coke ash and coke added.

IV. Net sulphur-free slag, limestone for coke ash and coke added.

V. Limestone, sand or its equivalents, and fixed carbon added.

In examples, given below, our standard analyses of coke and limestone (see under these items) have been utilized; also a sulphur solution of 1.40% S.

CASE I

LIMESTONE, SAND OR ITS EQUIVALENCE, AND COKE ADDED:

Sulphur in slag from limestone and sand or its equivalence $\frac{3.943}{100} \times \frac{100}{100} = 3.943\%$
 Sulphur in slag from coke $\frac{1.40}{100} \times \frac{100}{100} = 1.40\%$
 Sulphur in the final slag $\frac{100}{100} = 100\%$

Slag required to keep one part of sulphur in $\times\%$ solution = $\frac{100}{\times} = 81.433$

Slag shall have acids=bases.
 Acids must be brought in from other sources than the limestone; this may be sand or its equivalence.
 Slag from sand or its equivalence $= y = \frac{100}{\times} - y$

Slag from limestone is of 82.25% sulphur dissolving efficiency.
 $\therefore$ Slag from limestone $= \left(\frac{100}{\times} - y \right) \div 0.8225$

Limestone is 60.35% slag efficient.

$\therefore$ Limestone $= \left(\frac{100}{\times} - y \right) \div 0.8225 \div 0.6035$

Bases $= 0.4041 \left(\frac{100}{\times} - y \right) \div 0.8225 \div 0.6035$

But acids=bases.
 $\therefore y = 0.4041 \left(\frac{100}{\times} - y \right) \div 0.8225 \div 0.6035$

and sand or bases $= y = \frac{40.41}{0.9x} = 38.543$

Limestone required $= \left(\frac{40.41}{0.9x} \right) \div 0.4041 = \frac{100}{0.9x}$

Slag from limestone $= 0.6035 \left(\frac{100}{0.9x} \right)$

Total slag $= \frac{40.41}{0.9x} + \frac{60.35}{0.9x} = \frac{100.76}{0.9x}$

Carbon to melt this slag $= 0.228 \left(\frac{100.76}{0.9x} \right)$

Coke is 77.28% carbon efficient.

$\therefore$ Coke $= 0.228 \left(\frac{100.76}{0.9x} \right) \div 0.7728$

Slag from coke $= 0.2297 \left[0.228 \left(\frac{100.76}{0.9x} \right) \div 0.7728 \right]$

$\therefore \frac{100.76x}{100(0.9x)} + \frac{3.943}{100} \left\{ 0.2297 \left[0.228 \left(\frac{100.76}{0.9x} \right) \div 0.7728 \right] \right\}$

$= \frac{1.40}{100} + \frac{100.76}{100(0.9x)} + 0.2297 \left[0.228 \left(\frac{100.76}{0.9x} \right) \div 0.7728 \right]$
 and $x = 1.228\%$

One part of sulphur requires therefore:

limestone to flux coke $0.1713 \times 26.882 = 4.605$
 limestone for one part sulphur $= 93.433$ 95.038 stone

containing 35.400 base
 sand or its equivalence 36.543 sand
 coke 26.882 coke
 slag produced: From sand or its equivalence 36.545
 From stone 54.576
 From coke 6.175 97.296 slag

Sulphur in stone $95.038 \times 0.0015 = .14256$
 Sulphur in coke $26.882 \times 0.0088 = .23656$
 Sulphur in base for these calculations 1 1.37912 S

Sulphur in slag (per cent) $137.912 \div 97.296 = 1.417\%$

The cost of slagging one pound of sulphur will be:

for coke $\$2.20 \div 2000 \times 26.882 = \0.0295
 for stone $1.10 \div 2240 \times 95.038 = .0467$
 for sand or its equivalence $1.10 \div 2240 \times 36.515 = .0108$
 for slag $0.20 \div 2240 \times 97.296 = .0087$ \$0.0957

The value of one pound of sulphur-free slag will be: $0.0957 \div 97.296 = \$0.001$

CASE II

NET BASE, SAND OR ITS EQUIVALENCE AND COKE ADDED:

100 parts of coke require of net bases $9.63 - 2.706 = 6.924$
 100 parts of coke furnish of slag $12.629 + 6.924 = 19.553$
 Net bases added in per cent of total slag 35.41%
 Sulphur in slag $88 + 19.553 = 1.30\%$

Using these figures in formula of Case I we get:

$x = 1.2212\%$
 Slag $= \frac{100}{1.2212} = 81.89$

per one part of sulphur:

Coke $0.228 \times 81.89 \div 0.7728 = 24.16$
 Slag from coke plus bases added $24.16 \times 0.19553 = 4.72$
 Total slag $81.89 + 4.72 = 86.61$
 Bases in coke slag added $4.72 \times 0.3541 = 1.67$

Added thus:

Coke 24.160
 Base $(81.89 \div 2) + 1.67 = 42.615$
 Sand or its equivalence $81.89 \div 2 = 40.945$
 Slag produced 86.610

Sulphur in coke $0.2416 \times 0.88 = 0.2126$
 Sulphur in base for these calculations 1 1.2126 S
 Sulphur in slag (per cent) $121.26 \div 86.61 = 1.40\%$

CASE III

NET SULPHUR-FREE SLAG, NET BASE FOR COKE ASH AND COKE ADDED:

This is the same as Case II, with the following modifications added:
 Coke 24.160
 Base 1.697
 Slag—half acids, half bases 81.810
 Slag produced 86.600

CASE IV

NET SULPHUR-FREE SLAG, LIMESTONE FOR COKE ASH AND COKE ADDED:

In this case figures for coke as shown in Case I must be used
 $x = 100 \cdot 3.943 \left\{ 0.2297 \left[0.228 \left(\frac{100}{x} \right) \div 0.7728 \right] \right\} = \frac{1.40}{100} + \frac{100}{100} \left\{ 0.2297 \left[0.228 \left(\frac{100}{x} \right) \div 0.7728 \right] \right\}$
 and $x = 1.2277$
 slag $= 100 \div 1.2277 = 81.45$

per one part of sulphur:
 Coke $(0.228 \times 81.45) \div 0.7728 = 24.03$
 Slag from coke plus that from stone to flux ash $24.03 \times 0.2297 = 5.52$
 Total slag $81.45 + 5.52 = 86.97$

Added thus:
 Coke 24.03
 Stone for coke ash $24.03 \times 0.1713 = 4.12$
 Slag—half acids, half bases 81.45
 Slag produced 86.97

Sulphur in coke $0.2403 \times 0.88 = 0.21146$
 Sulphur in stone $0.0412 \times 0.15 = 0.00618$
 Sulphur for base for these calculations 1 1.2176 S

Sulphur in slag (per cent) $121.76 \div 86.97 = 1.40\%$

CASE V

LIMESTONE, SAND OR ITS EQUIVALENCE, AND FIXED CARBON ADDED:

Use formula in Case I, eliminating coke and substituting 1.40% for x .
 $\therefore$ Slag $= \frac{100}{1.40} = 71.42$
 $y = 0.4041 \left(\frac{71.43}{0.8225} - y \right) \div 0.6035$

Sand or base $= y = \frac{32.07}{0.9x} = 32.07$
 Stone $79.36 \div 0.4041 = 79.36$
 Slag in stone $79.36 \times 0.6035 = 47.89$
 Total slag $32.07 + 47.89 = 79.96$

Added thus per one part of sulphur.
 Fixed carbon $79.96 \times 0.228 = 18.23$
 Stone 79.36
 Sand or its equivalence 32.07
 Slag produced 79.96

Sulphur in stone $0.7936 \times 0.15 = 0.119$
 Sulphur in base for these calculations 1 1.119 S

Sulphur in slag (per cent) $111.90 \div 79.96 = 1.40\%$

REPORT No. ON LIMESTONE CONSUMED AT BLAST FURNACE No. 19

During the week ending: Date: 19

Date	Ship- ment No.	Weight in Tons of 2240 Pounds	ANALYSIS					STONE EFFICIENCY	Weight of Useless Stone Charged Into the Bl. Fce. = Col. 3 (100-col.9) 100	Re- marks
			SiO ₂ %	Al ₂ O ₃ %	Sum- mated Acid %	P %	S %			
1	2	3	4	5	6	7	8	9	10	
Daily: $= 100 - \left[\text{Col. 6} + (1.79 \times \text{Col. 6}) \right]$ For Week End Average see Below %										
Total										
average										

* AVERAGE CONDITIONS FOR THE WEEK

Average analysis:
 SiO₂ 5.80 %
 Al₂O₃ 4.00 %
 CaO 46.54 %
 MgO 2.78 %
 FeO 0.89 %
 P₂O₅ 0.023% P 0.01%
 CaS 0.340% S 0.15%
 CO₂ 39.63%

Going to the slag:

5.80

4.00

9.80 acids

46.51

2.78

0.89 50.21 bases

0.34 CaS

Total slag 60.35

Bases in excess 50.21-9.80=40.41

Total

Stone efficiency: $100 - [9.80 + (1.79 \times 9.80) + 0.023 + 0.340] = 72.30\%$

Flux efficiency = bases in excess = 40.41 %

Slag efficiency = total slag = 60.35 %

Sulphur dissolving efficiency (see calculations) 82.25 %

Cost per ton of 2240 pounds of net available base \$3.219

Cost per ton of 2240 pounds of limestone 1.279

Cost per ton of 2240 pounds of limestone due to sulphur alone 0.030

* Figures inserted are for exhibition only.

Electrochemical War Supplies

A Report of the Papers Presented at the Meeting of the New York Section of the American Electrochemical Society on February 11

Such a varied and attractive program of papers on "electrochemical war supplies" had been arranged for the meeting of the New York Section of the American Electrochemical Society on February 11, 1916, that the attendance broke all records. Not even standing room was left, and for the first time in the history of the Chemists' Club it became necessary to close the outside doors in order to keep within the police regulations as to the capacity of the hall.

Dr. Colin G. Fink, chairman of the New York section of the American Electrochemical Society, in opening the meeting said that it had been arranged to bring before the public a few of the remarkable achievements of American electrochemistry. "Owing to the fact that the dyeing industry of this country was not comparable to that of Germany, the American chemist has been branded as incompetent. The people as a whole are sadly ignorant of the wonderful accomplishments of the American electrochemists; they do not know and have never realized that the electrochemical industry of the United States is the very foremost of the world. Furthermore, the electrochemistry is a very important factor in national preparedness."

The Problem of Preparedness

Mr. W. L. Saunders, Chairman of the Board of the Ingersoll-Rand Co., President of the American Institute of Mining Engineers, and Vice Chairman of the Naval Consulting Board, was the first speaker. It is hardly necessary to say that he spoke very well. By some funny stories cleverly told—one of them how he once got a prize in chemical experimental work in his student days—he got his audience quickly into the best of humor and then launched into a discussion of preparedness.

The subject of preparedness is one in which I am very much interested. I cannot find myself getting into enthusiasm on the subject as to whether or not we should have an army of four hundred men or a million men; whether it should be a Continental Army or a State Militia, whether we should have instruction compulsory or instruction in the schools. I cannot get myself enthusiastic on the subject as to whether we shall have thirty-three dreadnaughts, forty-three or twenty-three, or whether we shall have a certain number of torpedo boats in proportion to a certain number of fast cruisers. All that, it seems to me, is a question of evolution. We are new in this question of preparedness. We are new as a war-like people. We do not know anything about it, and we had better reach a conclusion on the subject through deliberation and by a gradual process. But there is one thing that it seems to me that we do know—and if we do not we ought to know it—and there is one line of action in which we ought to begin at once, and that is, we should *begin at the bottom and prepare our industries.*

The first consideration is the industrial consideration of the country. Mines and mills and works and factories we have in large abundance. But they are all separated and disassociated, there is no relation between one and the other, there is no relation between any of the industries of the United States or the mines of the United States and the Government at Washington. You hear of a good many large concerns making large amounts of ammunition and making a good deal of money out of it. It is a new business, and it is attractive to them financially, but they know nothing about the relation of the United States to ammunition. They know nothing about what kind of shrapnel or shells the United States would require in case we were in trouble. In other words, the first question and the most im-

portant consideration in talking about preparedness against attack, is to have the industries of this country not only acquainted with each other and co-related, but in touch with the Government of the United States, so that the Government of the United States might tell them exactly what might be expected of them in case we ever get in trouble. No such thing has ever been done in this country. We know nothing about it, yet what little experience some of us have had on the Naval Consulting Board, we are inclined to believe that when the inventory is taken of the condition of the United States, the strength of the United States for peace or war will be found to be absolutely amazing. We do not know what we have got here in this country.

The Steel Corporation directors and officers know what they have got in the shops of the Corporation, and other concerns may be well acquainted with what the conditions are of their work, but we do not know the enormous volume and strength of the industries of the United States which might, if co-related and mobilized, put this country into an impregnable position against attack.

It seems to me, ladies and gentlemen, that it is far more important in the interests of peace and safety, for the United States to train its men in the works and have them organized so that they know what to do and do it efficiently, than it is to get them out in the trenches, or over at Plattsburgh, or out on the seas, getting trained to shoot guns, because if we got the organization in the works, and if we got the maximum resources in this country in iron and steel and coal and copper, we can get the men and we can train the men in a very short time to know how to handle those munitions and to oppose the strongest foe that the world can bring against us.

Mr. Saunders pointed out that the yearly coal consumption per capita indicates the industrial prosperity of a nation. This is five tons for the United States, four tons for Germany, four tons for England, 1.6 tons for France, 0.25 tons for Russia.¹

Anybody who has been in Russia as I have travelled over it several times, can see that the people of Russia, while they are intelligent, good people, yet they are not industrially prosperous. In other words, the individual in Russia can only produce what he can do with his hands. He will go out into the field and hoe and raise potatoes and cabbage. If he is working in the shops, he is working in some small establishment where his productivity is very limited. The same individual in the United States may produce ten to twenty times as much, because his work is done in factories on a large scale, where the productivity of the individual is multiplied five, ten and twenty times.

I have gone rather at length into this subject only to make plain the first point that is in my mind, and that is that industrially in times of peace, we are the strongest nation in the world. The three foremost industrial nations that I spoke of, the United States, Germany and England, produce and consume ninety per cent of the iron ore in the world. That is another indication of industrial prosperity.

Now, what is the difference between the United States and Germany, for instance? We have our industrial prosperity almost perfected on lines of peace. I venture to say that if the United States Steel Corporation or the Harvester Corporation or the Standard Oil Company, or any other of these large concerns which are run so well, so economically and so efficiently, were lifted bodily from this country and planted in either England or Germany, they would not be run any better. If they were lifted bodily and planted in Russia, they would fail, they would not be a success. I do not believe France could run them. Certainly Spain could not, nor Italy, and to take an exaggerated illustration, suppose they were lifted into China, can you imagine a great industry like the Steel Corporation run efficiently and profitably in China? No, it is impossible. In Japan they could not be run profitably. I have been in Japan and I have watched and studied the Imperial Steel Works with the

¹Compare the paper by J. R. Finlay, this journal, Sept. 1, 1915, vol. XIII, p. 647.

Government's money behind it, and yet they do not know how to produce steel rails as cheap as we do in the United States. They have not yet the efficient step that we have got in this country. Now Germany has got it, and Germany has got it not only for peace, but she has got it for war. But we have not got it for war, and it will take a long period of years to get it for war. I doubt whether our industries can be efficiently organized on a war basis in a period of even ten years, but we had better begin now. We do not control the world, we are only a small part of it, and a large part of it is in a conflagration at the present time. We had better prepare and protect ourselves and see that our house is in order, and we ought to begin at the bottom, and the bottom is in the industries of the United States.

And as a foundation we have the chemical industries of the United States, because chemistry is at the bottom of all our industry. We discover through chemistry. Chemistry is the basis of all our industrial prosperity, not only in mining and metallurgy, but in the arts in general. My whole experience in life has been a part of chemistry. I have been in business as an engineer, and week after week, in general work that I have done in connection with large corporations and in the management of work, have I found chemistry of advantage. Always questions come up wherein chemistry cuts an important figure—even in the question of drill steel, and why drill steel breaks under the hammer, and so, ladies and gentlemen, in conclusion I want to tell you that in industrial life, in both peace and war, the chemist is of the greatest importance.

Mr. Lawrence Addicks, president of the American Electrochemical Society, was unable to be present on account of illness, but had sent a letter in which he called attention to the fact that the war in Europe has accomplished two very important steps toward the military preparedness of this country. It has given a great many manufacturing concerns experience in adopting ordinary machinery to the special uses of turning out arms and ammunition, and it has sufficiently disturbed our imports to emphasize what would be our weak spots in self support in time of isolation. Aside from the broader view that nearly all production or manufacture contributes to war supplies, electrochemistry plays an important part in the production of some indispensable items—copper, aluminum, electrolytic zinc, various gases such as hydrogen, oxygen, chlorine, and acetylene, and finally the fixation of atmospheric nitrogen. Submarines could not be operated without the storage batteries and we must include wireless telephony. It may be included if the chemist and the electrical engineer put their heads together and do a little team work.

Fixation of Atmospheric Nitrogen

Mr. W. S. Landis, chief technologist of the American Cyanamid Company, said there was a widespread idea that Germany had been well prepared for the present war, as it had had large plants for atmospheric nitrogen fixation which could be diverted from fertilizer manufacture to munition manufacture, and that the development of an atmospheric nitrogen fixation industry requires years of work.

As a matter of record Germany at the outbreak of the European war possessed three cyanamid factories with a combined capacity of but little over 50,000 tons of cyanamid per year. There were then no arc processes at work in the country, and the Haber process was producing a comparatively small quantity of sulphate of ammonia.

In contrast with this Germany has to-day a production on an annual basis of almost 500,000 tons of cyanamid, and nearly 10,000 tons of arc-process nitric acid, all of which has been built and set into operation within eighteen months. Even the Haber process has been considerably increased in capacity, though the plant at Oppau suffered greatly, though indirectly, from an aeroplane visit. The present German investment in these atmospheric fixation processes is now over \$100,000,000, and Germany is enabled to meet not only its agricultural requirements for nitrogen, but its munition demands as well. In other words, Germany is now fixing atmospheric nitrogen in quantity such as to replace the entire importation of nitrogenous materials amounting annually to approximately 850,000 tons of nitrate of soda

and 40,000 tons of nitrate of lime, plus an indefinite amount of Norwegian cyanamid amounting probably to 20,000 tons annually. The munition plants are consuming nitric acid at a rate of 250,000 to 300,000 tons per year in addition to the above agricultural and manufacturing requirements.

Germany at the outbreak of the European war had no commercial plants oxidizing ammonia, though the processes now in use were then fairly well developed. It was not until after the beginning of the war that these processes were put to work on a large scale, and the tremendous amount of nitric acid required to maintain her powder supply is now almost exclusively obtained from these oxidation processes.

These figures are certainly impressive, illustrating what eighteen months can do toward meeting an emergency if the necessary funds are forthcoming and an intelligent organization directs their expenditure. We can well appreciate that this great feat was accomplished only by terrific strain upon the technical staff which had charge of the work, and undoubtedly at an extravagant cost.

The manufacture of cyanamid on this side of the Atlantic is conducted in Canada under American direction. It is carried on at a higher efficiency than in the German plants and a higher-grade product is made. Our transformation into ammonia is at an equal efficiency to theirs, and the operation is conducted with less men and with a simpler form of apparatus.

We further have in this country intimate knowledge of the design and experience in the operation of the successful ammonia oxidation process, and it will only be a matter of a short time now when a fair-sized plant will be producing nitric acid from cyanamid by this process in the United States. There are no problems concerned therewith, the solution of which is not now resident in the United States, and, therefore, we feel that this country is to-day in as good, if not in a better position to supply its own nitric acid for munition purposes than Germany was at the beginning of the war in July, 1914.

Hydrogen for Military Purposes

Capt. E. D. Ardery of the United States Army was the next speaker. He gave an outline of the various properties and general uses of hydrogen gas and then took up its applications for military purposes where it is used mostly for inflating balloons and also (in combination with oxygen gas) for welding and cutting. The lifting capacity of hydrogen gas is different, depending on the process of manufacture used; it usually ranges between 1.175 and 1.195 kg. per cubic meter.

Captain Ardery outlined the various methods for making hydrogen, of which there are many. The old method using iron filings or zinc with dilute sulphuric acid, the aluminium and caustic soda process used in the Russo-Japanese war, the silicon or ferrosilicon and caustic soda process and the method using a powdered mixture of ferrosilicon and sodium calcium oxide used by the French were mentioned. The calcium hydride or hydrolytic process, utilizing the reaction between calcium hydride and water, has also found some use abroad, the chief objection to it being its high cost. Hydron is a substance made in this country, which in contact with water generates hydrogen. The process of passing steam over red hot iron has also found application as has the coke and oil process. (For further information on these processes see this journal, Vol. IX, page 157, and Vol. XIII, page 567.)

The United States Signal Corps has made experiments on the refrigeration of illuminating gas for producing hydrogen and at Port Omaha, Neb., the army installed a plant for the generation of hydrogen by the electrolysis of water.

The chief objection in military work to utilizing the hydrogen set free from the electrolysis of water or salt solutions is the problem of compressing and transporting this gas. Portable plants are necessary to follow the army. Various portable plants are in use of various sizes. Hydrolith or calcium hydride and hydron are portable, as are also the installations

of several of the other processes. The Germans have achieved much success in transporting hydrogen gas in cylinders under pressure and also in pipe lines. It is claimed that in Germany large balloons are filled in 20 min. from hydrogen compressed in cylinders.

Niagara the Commercial Research Laboratory of the Nation

Mr. Albert H. Hooker, works manager of the Hooker Electrochemical Co., of Niagara Falls, N. Y., was the next speaker. He said that while the title, "New War Products," had been assigned to him for his paper, it hardly fitted the topic he had in mind. "However, it will do as well as any other to wander from."

One evening at Niagara Falls it was my fortune to sit next to an attorney (Mr. Scovele), who told me that some years ago he had been commissioned to visit London and place with a group of financiers an early issue of bonds of the Ontario Power Company. He was asked by these financiers what use his principals proposed to make of this development of about one hundred thousand horsepower. His reply to their question impressed me, for he stated that "when the Niagara Falls Power Company started their tunnel (about 1891), not one of the companies now using that power was in existence, and not only that but not one of the products now made by those companies, through the use of that power, was then known to commerce."

This statement, sweeping as it sounds, is nearly true, for aluminium, carborundum, alundum, silicon, artificial graphite, calcium carbide, cyanamide, ferrosilicon, ferrochromium, ferromanganese, along with electrolytically produced caustic soda, sodium, chlorine, chlorates, chloroform, carbon tetrachloride, etc., are all commercial products of the last twenty-five years, most of them having been developed through the impetus given by this Niagara Falls power development. The few that were made earlier were little more than chemical curiosities.

Cannot these be rightly spoken of as "new war products"? Certainly they played no part in the munitions, armament and equipment of our Civil War nor the War of 1870. But in what a sorry plight would any manufacturing country be to-day, and particularly either side of the present warring nations, without these materials!

Carborundum, alundum, aloxite, crysotol are all artificial abrasives used in modern grinding machinery for the manufacture of automobiles, guns, shells, shoes, armor plate and for the grinding of tools. There is hardly an industry where the tremendous decrease in production and increase in cost would not be felt were we without these artificial abrasives produced by the electric furnace at Niagara. Ferrosilicon, ferromanganese, ferrochromium, ferrotitanium, ferrotungsten and ferromolybdenum are all products which have become necessities in the steel furnaces of to-day, to the point where possibly 75 per cent of the steel production of the United States is dependent upon the products from the electric furnaces of Niagara Falls. What would we do in the way of modern open-hearth steel without ferrosilicon, or armor plate without ferrochromium, to say nothing of high-speed tool steels and all they mean for modern machinery manufacture, whether these machines are sewing machines, automobiles, agricultural machinery, steam engines, pumps, cannon or shells? England's embargo on ferroalloys would have crippled the industries of this country in a far more serious manner than the loss of all the German dyers, had not one of the companies at Niagara been able to divert a large block of power from the production of calcium carbide to the production of ferrochromium, ferrosilicon, etc. And still this would not have been possible were not the electrochemists, engineers and operatives already at hand and skilled in the art; and further this might not have been possible without additional power development had we needed at the same time, as Germany does to-day, every last ounce of carbide for the fixation of nitrogen.

Caustic soda is all important in the manufacture of soap, for the refining of oils, the mercerizing of cotton to produce artificial silk, and a hundred familiar uses, yet it takes on additional importance to-day when we think of caustic melts in the production of dyes, the manufacture of picric acid and other nitro explosives. Sodium we seldom see, and are likely to connect this substance with a few lecture experiments, yet metallic sodium made at Niagara Falls forms the basis for all of the cyanide in which so many of our mines depend for the recovery of the precious metals. When the German supply of cyanide was cut off, it looked for a time as if many mines would have to close. Here

again an increase in production made possible a restored balance, and fortunately a little power was available for the purpose.

Upon bleaching powder, liquid chlorine and hydrochlorites we depend for the bleaching of our cotton cloth, the bleaching of wood fiber for the production of book paper, the sterilization of water supplies of many of our cities thus preventing typhoid fever, dysentery and other diseases. The electrolytic plants at Niagara Falls form the center of this important industry. They, as well as all other electrolytic plants in the country, are dependent upon Acheson graphite made at Niagara Falls for their graphite electrodes. These chlorine products have all taken on a new interest, liquid chlorine as a means of offense and defense, chlorinated benzol, etc., as necessary intermediates for the production of dyes and explosives. Are these new plants and the knowledge and skill required to operate them—experience obtained at tremendous cost—to be scrapped and lost after the present crisis is over? Or, are we to continue the operation along the line of peaceful, constructive manufacturing, increasing our skill and knowledge and retaining a skilled force of workers, chemists, engineers and operatives? Much will depend on the policy of our Government.

Is not Germany, with her supply of Chilean saltpeter, cut off, absolutely dependent upon the fixation of nitrogen by the electric furnace, the electric arc or the use of electrolytic hydrogen for all of her nitro explosives? Were it not for her foresight in considering this eventuality and subsidizing the development of the nitrate industry in Norway with its cheap water power, and then carrying the development work to a point where in an emergency like the present even power produced from coal could for the time supply her needs for nitric acid from internal sources, how otherwise could she stand to-day with England's fleet in command of the means of communication with the Chilean saltpeter deposits?

A NEW PROPOSAL OF NIAGARA FALLS POWER DEVELOPMENT

What are we doing to-day to supply our needs in a like emergency? I have a remedy to propose, and one which I feel it a duty to urge, for your earnest consideration.

As this was written, I saw from my window the waters of the Niagara River flowing by with a capability of being developed into perhaps five million horsepower—the most uniform and constant water power in the world. I am very fond of the impressive beauty of its mighty falls and the wonderful gorge and rapids below, and only as a last resort in the event of a national defense necessity would I do anything to injure that landscape. Such injury, however, is not necessary. As I study the daily moods of the falls, I see the ebb and flow of water due to the direction and velocity of the wind on Lake Erie, making far greater difference in the volume of water passing over the brink of the Falls than is caused by the present diversion of water producing some five hundred thousand horsepower. I also see that the beauty of the falls is not at its best when the largest volume of water is passing over its brink. From careful study I am satisfied that well over one million horsepower more could be diverted, and not an iota of injury would be done to the scenic grandeur of the cataract if a little engineering skill were used in placing the proper brakes and deflectors. If this is true, think of the tremendous increase in national efficiency and preparedness this development would mean. Arrange now with Canada for a development of water power at Niagara three times as great as at present—the time is ripe.

For every one hundred thousand horsepower diverted, provide that say ten thousand horsepower shall be devoted to the fixation of atmospheric nitrogen. The more varied the methods used the better. Make Niagara the commercial research laboratory of the nation in this field by supplying private enterprise with power at nominal cost for this purpose. Under these conditions, power, even if developed by private enterprise in large amounts, could in the above percentage be supplied as cheaply if need be as Norwegian power, and would be infinitely better adapted and centralized for the purpose. Such power would be within a night's ride of Washington, New York or Chicago. Already located at Niagara is the largest group of electrochemical workers in the world. Such a development would double their number. Is it through lack of foresight or "a dog in the manger policy" that some of our largest and most important electrochemical industries are even now compelled through lack of cheap power to go to Norway and other fields, there to start the training of a foreign army of electrochemical workers upon foreign soil, while unused water which could be utilized without injury goes to waste?

I have been told that the Niagara River is a border stream; that plants situated near that border would be particularly open to foreign attack. Conceding only that Eng-

land be our enemy, this is true. But did Germany give heed to an even stronger reason against making her experimental and peaceful development in Norway, where as at Niagara the economic conditions were right?

Not in a day, a month, nor a year can these problems, alike of peace and war, be worked out, the equipment developed and installed, and above all, the workers trained. The goal is an ever-increasing internal independence both as regards food and chemicals. For an increasing population this may well mean the regeneration of a worn-out soil, the refertilization of our farm lands from New England to the West with ammonia and nitrates from the air. Every farmer, every bread eater is interested in the result. Let me in this connection read two extracts which I recently clipped from the daily press:

"London, Jan. 21.—The urgent necessity of speeding up the supply of munitions has determined the Government to put into force immediately plans for the dilution of skilled labor with semi-skilled, unskilled and female workers in all controlled establishments. In a statement on the subject in the House of Commons to-day Premier Asquith announced that the Government was convinced that this plan offered the only prospect of securing a sufficient supply of munitions to enable the war to be brought to a speedy and successful conclusion. 'Any lack of munitions,' continued the premier, 'would exact a heavy toll in lives of soldiers. It is quite impossible that foreign supplies can take the place of the home production of munitions, but even if those sources of supply were indefinitely extended, the immense demand thereby caused upon our financial resources and our shipping would present insuperable difficulties.' Premier Asquith stated that both the owners of the controlled establishments and the representatives of the trade unions had loyally pledged themselves to support the Government in the scheme of labor dilution. Considerable progress had already been made in certain districts, but he regretted that what had been accomplished fell lamentably short of the national requirements in the present emergency.

"Brigadier General Crozier has given some figures to the Senate Committee on Military Affairs which should put an end to the movement to have the Government build its own munitions plants. He estimates that the cost would be about \$400,000,000, and that 750,000 workmen would have to be employed. This would supply 1,000,000 men in the field and a reserve of 1,000,000 men with guns and ammunition. General Crozier believes that the Government could do better with private manufacturers, whom he would have the Government encourage. As has been proposed, the Government could supervise the manufacture of arms and ammunition and in a considerable degree regulate prices."

The provision of electrochemists, mechanical engineers and operators in these specialized industries in times of peace as an emergency precaution is fully as important as compulsory military service and should be considered as an element of the same broad plan. My wife says she objects to raising her boy to be a soldier, and yet would be the first to tell him to go to the front if his country needed him. Instead, however, I am training him to be a chemical engineer, where I feel that in times of peace and without economic loss he will be in constant training to serve his country's needs to the highest degree should war arise.

Think you that Germany and Switzerland are only interested in the electrochemical and synthetic dye industries because of their economic value in time of peace? They are of tenfold greater value as measures of preparedness. The same benzol, toluol, caustic soda, nitric acid, chlorine and sulphuric acid used in times of peace for the manufacture of dyes are used in times of war for the various nitro explosives; the same equipment is used and the same army of skilled chemists and workers familiar with the latest details of nitration process are in constant training.

Should we not consider the training of this industrial army, the preservation of our growing dye industry, the development of our water power and electrochemical industries as a matter of particular urgency now as a measure of preparedness for national defense?

Metallic Magnesium

Dr. William M. Grosvenor, consulting chemical engineer, New York City, then presented a paper on metallic magnesium (one of the promising baby electrochemical industries of this country, as the chairman remarked). In the introduction he cleverly offered his "qualifications (or apologies)" for speaking on the subject. "There are but two: The first is what I do not know about it. The second what I suspect but am not at liberty to tell."

THE ELEMENT

You all know the chemical position and character of magnesium, leading member of the alkali earth division of the second group, atomic weight 24, closely related in its properties on the left with Na 23, on the right with Al 28, with Be 9 above it and Ca 40 below. Note the comparative lightness: Sp.G. Mg. = 1.75, Na = 0.98, Al = 2.6, Be = 1.64, Ca = 1.6. Also the melting points: Mg. = 750 deg., Na = 96 deg., Al = 660 deg., Be = about 900 deg., Ca. = about 760 deg. All are more or less soft white metals, all show great avidity for oxygen, decomposing water more or less readily. None except aluminium has found large commercial use, but of the others magnesium leads the list by a long distance.

USES

Its chief uses are:

Scavenging alloys, i.e. clearing up oxides of other metals and making far denser, cleaner, stronger and more homogeneous alloys. Valuable in aluminium nickel, copper, brass, bronze, etc., and special steels, because of its intense avidity for both oxygen and nitrogen.

Alloying itself, with aluminium or aluminium containing traces of one or more of the other metals, Cu, Ni, Zn, Pb, Bi, Sb, Fe, etc. It greatly modifies crystallography and physical properties, alloys readily with most metals, and melts at a convenient heat.

Illumination, as in military uses for shrapnel trailers, star bombs, flare lights, etc., and in photography for flash-lights. Its easy inflammability (about 800 deg. C.), the high heat of combustion (134,000 cal.), the relatively low heat of vaporization (1100 deg. C.), the intensely white oxide produced and the high temperature of volatilization of this oxide are the essential factors.

MAGNITUDE AND PRICES

How much is used? A far more agitating question than how old is Anne. Records of imports for the year prior to the war indicated 38,000 lb. About 100 lb. a day, therefore, seemed to be a safe production to undertake. Prices before the war had been very steady around \$1.45 per pound, but it seemed reasonably certain that the cost need not exceed \$1 per pound. After the war began the prices being paid for remnants of imported lots quickly rose to \$2.50.

Some of the first demands here were from wholly unexpected quarters, in surprising amounts and at amazing prices. The most urgent, almost pitiful demands, came from quarters that were not even suspected to be interested in the least. One consumer has contracted for 24,000 lb., another for 15,000 lb., these two alone taking for strictly domestic use more than was supposed to be the total importation. There are at least three other buyers of similar quantities, but exact amounts are not yet established by yearly contract, and even at present prices the consumption for strictly domestic use is about 50 tons.

We found that a great deal of the material was being imported under other names and most carefully disguised—secrecy being preferred to economy. Prices as high as \$10 per pound were gladly paid at first for domestic product. For some months then the prices jumped around from \$5 to \$7.50, but every effort was made to reduce conditions to some sort of order by dealing direct with the consumer. This was partly the result of a deliberate policy for better and more intelligent service of the consumer's precise demands as to quality and delivery, but partly also the result of meeting quite unexpectedly the competition of our own product at prices from 25 per cent below to 50 per cent above the prices we had made. Some of New York's clever war brokers added 10 per cent each through a chain of four or five middlemen. Others assumed direct quotations to have already been through this process and knocked off 20 per cent, trusting that "real cash business" would squeeze down the middlemen they supposed to exist and still leave 5 per cent for the real seller. Now, however, for a number of months the price has been practically fixed at \$5.50 per pound of "guaranteed 99 per cent," actually about 99.5 per cent. Occasionally a lot that has been picked up in the antebellum market for speculation is let go at lower figures or a lot of lower-grade material comes on the market from abroad, but there is practically no volume of these sales.

In spite of the beautiful appearance of the German bars they rarely exceeded 98 per cent and often fell as low as 96 per cent. The process of extrusion concealed impurities by drawing them out into minute threads. It is safe to say that the regular commercial grade of metal made here now is superior to anything ever imported.

REASONS FOR THESE PRICES

It may seem ridiculous to ask or pay such prices. Let us consider. The alloy market constitutes the bulk of the

business, and governs prices. In aluminium castings, for instance, about less than 2 per cent of magnesium cleans up the aluminium and leaves $\frac{3}{4}$ to $1\frac{1}{2}$ per cent in the casting, about doubling its tensile strength, and quadrupling its resistance to shock or jar. It reduces the cost of machining more than 50 per cent, halving the number of resets on the cutting tool, giving clean cut machine surfaces, and permitting a polish to be secured with the last cut instead of a separate operation. With care, $1\frac{1}{2}$ per cent of magnesium at \$5.50 per pound is all that is needed, i.e. $8\frac{1}{4}$ c. per pound of casting actually required to do the same work. The increase in strength means, in some cases, a reduction in weight of casting of 50 per cent. The reduction in casting weight is generally not less than 25 per cent. The weight of a pure aluminium casting may therefore be reduced if this $1\frac{1}{2}$ per cent of magnesium is used by from 25 to 50 per cent. This is a great saving even at normal prices of aluminium since it amounts to about one-fourth of 20c., or 5c. With aluminium at 60c. it amounts to 15c. worth of aluminium saved for a stronger and more stable mechanical result. The saving in machine work alone when the casting is to require much machine work more than pays for the use of magnesium. So much for the consumer or user.

Now the manufacturer of magnesium has certain considerations (of necessity rather than mere excuse) for the high prices. Cost of production abroad prior to the war approximated \$1 per pound. Sales in England were about \$1.30 and here about \$1.45 per pound. At that time $MgCl_2 \cdot 6H_2O$ was selling for about \$18 per ton. Present prices here are now about \$60, nearly four times normal. Other chemicals used in the manufacture have increased to ten times their normal price.

One other factor, i.e. insurance, must be considered in two forms. First, the insurance against cut prices and dumping that may come immediately upon the close of the war, making the plant and market-development work absolutely worthless. Second, the insurance against partisan interference. As a matter of fact, in the case of two plants not a pound of material from either of which has gone for foreign military purposes so far as we know, there have been repeated efforts at molestation and some serious interruptions. Finally, there is the general consideration of relative price advance as compared with other materials: H_2SO_4 , \$12 to \$60, or five times; nitric, 4c. to 12c., or three times; NaOH, $1\frac{1}{2}$ to $5\frac{1}{2}$, nearly four times; Na_2CO_3 , 1 to 4, and numerous other commodities not directly affected by inability to import.

In considering prices it is well to mention separately export prices. Before the war nearly all the magnesium for England, as well as the United States and France, came from Germany. Since the war both France and England are producing in considerable quantities of excellent purity. This fact and the failure abroad to realize the strenuous conditions here, account for the unwillingness of buyers abroad to pay more than \$3.50 for powdered metal (all the above named prices were ingot or bar).

PRESENT PRODUCTION

At present there is being produced here at two points about all the present alloy market will absorb, and an increase of plant is being made of about 25 per cent the present capacity. One other producer makes only about his own requirements. Two others are soliciting business, but have failed to fill orders—in one case the order is now over a year old and still stands unfilled. All told, we believe the present production is at the rate of something over a million dollars a year, and will be slightly in excess of the present domestic needs.

POSSIBILITIES

The use of the metal for scavenging purposes depends on price of metal compared with price of material to be scavenged. For use with copper, brass, bronze, etc., the magnesium can be used at far higher prices than for steel. But the big consumption of the material can only come when it directly replaces aluminium as the predominant metal in the alloy, and arrives at a correspondingly low price. It makes beautiful castings, machines easily and well, is about a third lighter than aluminium, and can be made about two to four times as strong. The coefficient of expansion reported is practically the same as aluminium. When properly pure (over 99.5 per cent), it is apparently quite as resistant to corrosion as aluminium, equal if not superior in electrical conductivity (about half that of copper), and superior in heat conductivity to aluminium (also about half that of copper).

PROCESSES

1. Reduction of fused $MgCl_2$ with Na.
2. Electrolysis of the fused double chloride, usually $MgCl_2 \cdot KCl$.

3. Reduction with carbon. (Patented.)
4. Electrolysis of dissolved MgO . (Applied for.)
5. Reduction of fused $MgCl_2$ with Al. (Applied for.)
6. Reduction of oxide or carbonate to slag-forming residues. (Applied for.)

And some others.

The first process involves the production of metallic sodium, and we have been using the Castner process for this purpose to satisfy ourselves just what the sodium would cost and what the possibilities in this direction were. Existing conditions, the demand for sodium and sodium peroxide, forbid its consideration with a minimum of about 2 lb. of Na consumed for every pound of magnesium produced and the necessity of producing dehydrated fused $MgCl_2$ to start with.

The second process has been perfected and is very largely used abroad. We have commercially used and studied the process here and, with the cheapest water power and chloride, prices under normal conditions by this process must rule above \$1.

The third process, reduction with carbon, is absolutely fascinating in its possibilities. The product is a black or gray powder. Believing such a product would be valuable, the manufacture was carried out on a scale of about 25 lb. per hour. As the difficulty of selling the product became apparent, much time and effort were devoted to attempts to recover the metal in fairly pure form. Owing to serious objection both on the side of cost and regularity of product this process was superseded.

The other processes will be discussed on some other occasion when the engineering problems they involve are believed to be finally solved in the best way and the patent office has finished considering them. The chemical side of each has been thoroughly worked out, however, so that some conclusions may be drawn from the large laboratory or small commercial operations. These may be of considerable interest.

At least one of the processes appears to be adapted to produce directly metal averaging 99.6 per cent purity in tons per day instead of pounds. Laboratory tests give a raw material cost of 4c. per pound of magnesium, and indicate a fuel cost which approaches 3c. as a theoretical limit, though the practical figure will probably be several times as high. The final selection of various possible engineering means and methods remains to be worked out, but it scarcely seems possible that either labor or repairs should exceed 2c. per pound. Thus if commercial yields maintain the experimental level and three times the theoretical power is commercially required, we have prospects of a net factory operation cost (without interest, amortisation, insurance, patent, administration or selling) of 17c. per pound. If only 75 per cent yield is obtained this net factory cost would be about 22c., or a total cost with all overhead expenses of 35c. and a selling price of 40c. to 50c., according to tonnage.

It may be asked with perfect propriety: "Why talk about it now? Some fool will certainly want you to make a contract with him at lower prices, possibly at 50c. He will not realize that it is only the present price of \$5.50 that justifies or even makes possible the thousand and ten-thousand dollar experiments that have been tried and must be tried again and perhaps again during the next three to five years before the tide turns. You will be pestered for years with this 17c. talk." We have carefully considered this probability. The men who are doing this work do not cultivate talkativeness as a preference. Just at this time, however, certain considerations of public welfare should take precedence of preference. National self preservation demands the subordination of personal interest. If we expect representatives at Washington to jettison the pork barrel, the army post, the high-tide navy yard, and political trading generally, and give us a fighting chance for our lives in the scrap that is certainly coming, we must set the example of considering national interest first. If we are to have the army and navy preparedness for which we have already wasted more money than Germany has paid for her wonderfully efficient fighting machine, if we are to have any preparedness instead of repairs or regrets, we must co-operate with all we have in service, information and suggestion.

Therefore, at the risk of criticism and possible financial sacrifice, it seems to be a duty at this time to point out what may possibly be expected of magnesium. Few realize the extent to which it is valuable in military work. One of the great foreign explosive experts stated that he would be glad to pay \$1.50 per pound for 500 tons. A single contract for shrapnel being executed in this country would require about fifty tons. The illuminating bombs to make daylight over the enemies' works and trenches consume large quantities. The trailer attached to shells serves at night to show the effectiveness of the fire. For all these purposes mag-

nesium produces a result that cannot be approached by antimony or aluminium. Consider what it means to aeroplane, dirigible and motor construction, to high-speed engines of every type, to reduce weight one-third and double strength. A material that has a density of 1.75 and may be hot rolled to 35,000 lb. per square inch or cold rolled very much higher.

Although five or six men are being kept practically all their time on the development of these possibilities, the broad, quick development is a task for the energy of hundreds. Feeling the responsibility which knowledge of the possibility entails it became the duty of those in charge of this work to let others know and be active in their side of preparation, to apply the material.

Liquid Chlorine and Electric Steel

Dr. G. Ornstein, chemical engineer of the Electro Bleaching Gas Company, then read a paper, illustrated by lantern slides, on liquid chlorine. This paper was published in full on page 215 of our issue of Feb. 15.

Dr. George W. Sargent, vice-president of the Crucible Steel Company of America, spoke briefly and, in view of the late hour, promised to present his paper on electric steel at a future meeting of the society.

Electrolytic Zinc

The last paper on the program was by Mr. W. R. Ingalls, editor of *Engineering and Mining Journal*, on electrolytic zinc. In the absence of the author it was read in abstract by Dr. J. W. Richards.

Without any doubt, the most important thing in the metallurgy of zinc in 1915 was the inauguration of electrolytic zinc production direct from ore on a large experimental, even a commercial, scale at several places, the most important of these being at Anaconda, Mont., where the production of electrolytic spelter at the rate of about five tons per day was begun. The results are considered so favorable that the Anaconda company has commenced the erection at Great Falls, Mont., of a plant capable of producing 35,000 tons of electrolytic spelter per annum. With regard to the nature of the Anaconda process, Mr. Laist, who is responsible for it, has written me as follows:

I can hardly claim that we have accomplished anything especially new in this line, except in so far as we have done on a somewhat larger scale what had often been done before by others in the laboratory in a smaller way. Briefly, the process consists of concentrating the zinc ore, preferably by flotation, so as to make a concentrate with as little insoluble matter as possible and as rich in zinc as the nature of the ore allows. This concentrate is roasted in two of the furnaces of our copper-leaching plant, so as to produce a calcine containing from 2 to 3 per cent sulphur, most of which is present as sulphate sulphur. The temperature is not allowed to exceed 1350 deg. Fahr., under which conditions the formation of zinc ferrite is not pronounced.

The calcine, after cooling, is treated with a solution containing sulphuric acid, which dissolves the zinc and a little of the iron. A small amount of manganese dioxide is added for the purpose of oxidizing the iron, which is then precipitated by means of a small amount of powdered limestone. Any arsenic or antimony is carried down by the precipitated ferric hydroxide. The resulting solution contains nothing but zinc, cadmium and copper, and is separated from the residue by filtration. The residue contains the lead, silver and gold and part of the copper originally present. The solution is treated with metallic zinc to precipitate the copper and cadmium, and is then pumped through a clarifying filter-press into a storage tank, from which it goes to the electrolytic cells. The cell room contains forty-two tanks, which are in no way different from those commonly used for copper refining. Here the zinc is deposited on aluminium plates.

The solution from the cells contains sulphuric acid and is used for leaching a fresh charge. The zinc deposits on the aluminium plates are stripped off every 48 hr. and sent to the melting furnace. At the present time we are making about five tons of zinc per day of a high degree of purity.

I will add to this that the leaching is performed in Pachuca tanks, the lixiviant being spent electrolyte plus the quantity of fresh acid required. The anodes of the electrolytic cells are of pure lead. The solution is electrolyzed at a current density of 20 to 30 amp. per square foot of cathode surface, the general practice being about 23 amp. The voltage drop per cell varies from 3.8 volts at the head cell of the series (21 cells in cascade series) to 3.4 volts in the tail cell. Current efficiency is from 93 to 94 per cent.

Apart from the Anaconda work, the most ambitious plans carried on in 1915 were those of the Consolidated Mining and Smelting Co. of Canada, which continued the experi-

mental work begun several years ago. In the last official report of this company it is stated that spelter of good grade has been produced at the rate of 1000 lb. per day from ore from the Sullivan mine, and that the results were sufficiently promising to warrant the building of a plant capable of producing 25 to 35 tons of spelter daily. Construction of this plant is well advanced, and it is expected to be in operation early in 1916.

Electrolytic zinc was also produced in 1915 on an experimental scale by the Electro Zinc Co. at Welland, Ont., while some work in this line was done at Keokuk, Iowa, and at Bully Hill, Cal., and there were one or two other operations (one of these employing the Isherwood process) that may not yet be mentioned publicly. The work at Welland is unique in that the dissolving of the zinc and the electrolysis of the solution is performed in the same vat, the cathodes being inclosed within canvas bags. All of the other work, so far as I know, is being done on lines similar to those at Anaconda.

Before going any further, let it be well fixed in the mind that the conditions that have existed in the zinc industry during the last year are not only unprecedented but also it is certain that they cannot be otherwise than ephemeral. They have been due to a shortage of metallurgical capacity, not of ore in the least degree, and that shortage is being reduced with extraordinary rapidity. In the meanwhile, however, there has naturally been a huge metallurgical margin—even \$60 per ton of ore against a normal of about \$15—in the manufacture of common spelter and with such a margin it has been good sense not only to commit metallurgical crimes, but also to institute new processes that would not ordinarily be profitable. In the manufacture of high grade spelter the margin has been much higher, so much so that the possibility of it would two years ago have been considered nothing less than preposterous.

Now, the electrometallurgy of zinc is no new thing. The electrolytic refining of impure spelter was tried on a large scale by Nahnhen in Upper Silesia in the '90s, the hydrometallurgical-electrometallurgical treatment of zinc ore was essayed disastrously by Ashcroft at Cockle Creek, New South Wales, in a works costing about one million dollars. Dr. Hoepfner developed a process that was put into use at Führfort on the Rhine and at the works of Brunner, Mond & Co., at Winnington in England. At the former it has been abandoned after a short time; at the latter it has been continued through a long series of years, making a few hundred tons of spelter annually, and is in use at the present time. The electrometallurgy of zinc has therefore a commercial history of respectable antiquity.

In the early days of the art, both commercial and experimental, difficulty was experienced in obtaining dense deposits on the cathodes, spongy zinc being a stumbling block, but while this matter required some study for its mastery, it was manifest that the real difficulties of this process were the getting of zinc into solution rather than out of it, and the large amount of power required for zinc precipitation.

With regard to the former point, I refer to the formation of insoluble ferrite of zinc in roasting, with the consequence of relatively low extraction of zinc. That is experienced in the case of many, perhaps most, ores that it is desired to treat. To illustrate, roasted Joplin blende may be leached with sulphuric acid so as to cause it to give up 97 or 98 per cent of its zinc, the residue being a white silica sand, but nobody wants to treat Joplin ore by a hydrometallurgical process for the reason that it would be less economical than ordinary smelting. On the other hand, certain mixed ores high in iron like those of Leadville, Col., may give up only about 65 per cent of their zinc. So low an extraction would in itself be prohibitive in most circumstances in ordinary times. It is possible that the roasting might be conducted in such a way as to steer clear between the Seylla of zinc ferrite on the one hand and the Charybdis of undecomposed zinc sulphide on the other hand, but that question has not been investigated with definite results, so far as I know. With regard to the high power required for the electrolysis of zinc solutions with insoluble anodes, the expense of it, when imposed upon the cost of roasting, leaching, remelting cathodes, reworking of products, etc., is likely to make the cost of hydrometallurgical-electrometallurgical zinc extraction too high to be ordinarily considered.

I have, therefore, repeatedly expressed the opinion that metallurgical processes of this sort were unlikely to be successful commercially unless: (1) Exceptionally cheap hydroelectric power, such as the \$6 or \$7 per annual horsepower of Norway and Sweden were available; or (2) unless use could be made of the anode reaction, such as the

*Compare, however, the figures given by Mr. C. A. Hansen on the results obtained at Bully Hill (this journal, Feb. 1, p. 120).—Editor, MET. & CHEM. ENG.

liberation of chlorine by the electrolysis of a chloride solution and the employment of it for some chemical manufacture, as at Winnington, England; or (3) unless certain especially favorable conditions otherwise existed. By the last I mean such things as high grade of the run-of-mine ore, a kind of ore that will give up a high percentage of zinc by lixiviation with sulphuric acid, an ore high in silver, and possibly lead. These points are almost determinative. In the pyrometallurgy of zinc the extraction of silver is, perhaps, about 65 per cent. In the hydrometallurgy of zinc it ought to be upward of 90 per cent, perhaps as high as 95 per cent. The situation with respect to lead is somewhat similar. It is needless to dwell upon the importance of this in the cases of ore exceptionally high in silver.

Now, in the treatment of the Butte ore at Anaconda, about all of the favorable conditions that I have enumerated under the third head exist. The ore raised from the mine is of rather high grade, it is of a character that enables 90 per cent of the zinc, or more, to be extracted by sulphuric acid lixiviation, and as zinc ores go, it is exceptionally high in silver (the concentrated ore going 20 oz. silver per ton, or thereabouts). Moreover, the Anaconda company is introducing zinc extraction in connection with its other great metallurgical work, thus dividing general and administrative expenses, etc. It is able to obtain moderately cheap power at Great Falls, and finally, what is not least in importance, it possesses about the best metallurgical organization of any concern in the United States, and is instituting this new process at a time when there ought to be commercial profit in spite of any imaginable infantile disorders. I am not free to communicate such figures respecting the Anaconda results as I know, but I may say that the Anaconda management is thoroughly aware of the exceptional conditions existing in the zinc industry at present and is nevertheless of the opinion that with its peculiarly favorable circumstances it can continue the production of electrolytic zinc in competition with everybody else in the normal times, or even in the hard times that may be experienced after the termination of the war. The promise of the development of the hydrometallurgy-electrometallurgy of zinc as a commercial art on a large scale has, therefore, already become a prospect. There is to be such an art. The magnitude that it will attain, and its effect upon the zinc industry of the world, remain for the future to tell, but that it is going to have an early and important influence is not to be doubted.

Turning attention to some of the technical features of electrolytic zinc production, the conditions governing the electrolysis of zinc solutions were exhaustively treated by Dr. Victor Engelhardt in a paper read at the first general meeting of the Gesellschaft Deutscher Metallhütten und Bergleute and published in *Metallurgie* a few years ago. A summary of Dr. Engelhardt's conclusions, together with some additional notes, was published by Prof. J. W. Richards in "Transactions of the American Electrochemical Society, XXV," pages 281-290. The ideas of Dr. Engelhardt, who is the chief engineer of the electrochemical division of the Siemens & Halske Company of Berlin, are exemplified in what are called the Siemens & Halske and Isherwood processes. However, in the late development of zinc electrolysis "processes" and patents have played but slight part. With recent experimenters the matter of spongy zinc deposits appear to have been among the least of the difficulties. Mr. Keating succeeded several years ago in depositing smooth, solid zinc on his cathodes at Bully Hill, Cal., while as for Mr. Laist, he accomplished this part of the process as a matter of course, just as simply as if he were depositing copper, the necessary precautions as to purity of solution, etc., being naturally taken.

With regard to the grade of electrolytic zinc, high purity is easily obtained. This is something that is far more under control than in refining by fractional distillation. Lead ought not to go appreciably into solution at all, while iron, copper and cadmium—the other common impurities of spelter—are readily precipitated from the solution. The spelter first made at Anaconda was higher in cadmium than is permitted by the standard specifications for "high-grade." At that time zinc dust, more or less impure, was being used as the precipitant for cadmium. Running the clarified solution through a tube mill filled with zinc balls corrected this, and the grade of the spelter was then raised to upward of 99.9 per cent. Brunner, Mond & Co. have been for many years guaranteeing their electrolytic spelter at 99.95 per cent, and there is no reason why the Anaconda spelter should not be made as good as that.

Is electrolytic zinc extraction going to revolutionize the metallurgy of zinc? Unqualifiedly, no. When the zinc industry returns to its normal status, conditions will be in the main as they were before the war, and the principles that I have previously stated will continue to obtain, with

the difference that some people will have learned the details of the art, will have gone through the period of infantile mistakes in a time when almost any mistake was of no great consequence. By that time some of the concerns possessing exceptionally favorable conditions—Anaconda, if any—may be able to continue. Others will not.

However, there are certain new industrial features that can not yet be clearly estimated and may have a modifying effect upon this forecast. One of these relates to the matter of high grade zinc. Previous to the war that class of spelter was produced in limited quantity and sold at a premium over common spelter of about 2½c. per pound. Inventors, promoters and others who talked about making such zinc were discouraged from reckoning upon the premium by the dictum that the market would not take any more than the then supply, which was indeed artificially limited, and that it was unsafe to count on anything but the price for common spelter. During the war high-grade spelter has fetched 40c. per pound, and at times the demand for it has been insatiable. This demand has been especially in connection with the manufacture of ammunition and may be expected to cease with the war, but will the advertising that high-grade spelter has had and the wider knowledge of its peculiar properties that has been acquired give it a more extensive use in the peaceful arts and a maintenance of the premium for it that will be to the advantage of the electrolytic producer? Or, will it become a drug in the market, with entire disappearance of price differential? These are questions that nobody yet knows enough to answer reasonably.

Another new and uncertain factor is the bearing of the flotation process of ore concentration upon the metallurgy of zinc. I think that this had a good deal to do with the institution of the Anaconda work. About all metallurgical work is a sequence of steps of concentration and refining, treating the bulk of the ore by a cheap but wasteful process and delivering a concentrated product to a more costly but less wasteful process. Now, most experimenters in the hydrometallurgy and electrometallurgy of zinc heretofore have contemplated the application of a costly process to the run-of-mine ore. The flotation process has enabled ore to be concentrated at relatively small cost with but slight loss. Let it be observed, therefore, that Mr. Laist is applying his costly process not to run-of-mine ore, but to a flotation concentrate in which about 90 per cent of the zinc is concentrated in about one-fourth of the original weight. This is the new and important feature of recent zinc electrolytic work.

We must let our thoughts run a little further ahead. The treatment of flotation concentrate is one of the present troubles of the zinc smelter, owing to its excessive fineness, which produces difficulties that it would take me too long to describe. Yet the proportion of this class of ore that the zinc smelter is getting is still relatively small. The supply of it is, however, bound to increase, and when it becomes large the troubles of the zinc smelter will really begin. Now the hydrometallurgist will have the same troubles up to and through the roasting of the ore, but he will be free from those that arise in the distillery. In so far he will have an advantage over his brother pyrometallurgist, but whether it will be a weighty advantage I do not venture to offer an opinion.

Another thing that may help the hydrometallurgist is improvement in the method of roasting. Twenty-five years ago he used to talk about sulphate roasting. He did not in practice find the idea to work out as well as he expected. While he might be able to render 40 or 50 per cent of the zinc soluble in water, he found there was too much undecomposed sulphide left behind after leaching with sulphuric acid. So then he said he would roast the ore, completely leach all the zinc with sulphuric acid and be done with it. To his surprise he found that much of the zinc had been rendered soluble by the formation of zinc ferrite if iron were present in the ore, as was almost always the case. The roasting of ferruginous blends in such a way as to convert all of the zinc into sulphate and oxide, avoiding both sulphite and ferrite, which may perhaps be done by correct control of temperatures, perhaps by some other control, is an interesting subject for investigation. Mr. Laist has given some attention to this by carefully limiting the temperature of his roasting furnace. However, I think that perhaps the danger of ferrite formation is not very great in the case of his ore. Anyway, I know that it is not in roasting some similar ore of Butte without much regard to the matter of temperature.

In view of the very late hour the discussion was very brief. In reply to a question by Dr. Baekeland, Mr. Landis replied that the cost of getting nitrogen gas from liquid air is one of the smallest cost items in their cost sheet.

The Operation of the Blast Furnace

BY J. E. JOHNSON, JR.

(Concluded from Page 215)

The Progressive Changes in the Ascending Gas Column

Turning now to the changes in the gas column, we find that these are of three separate kinds, but owing to the fact that the physical state of the gas does not change they are less sharply divided into zones than in the case of the solid and liquid materials. The three kinds of change are chemical, thermal, and physical. That is, change in composition, in temperature, and in pressure and density of the gas.

Considering first the chemical changes we have the blast entering, in coke practice, in a highly heated condition at the tuyeres, and in good practice distributed by their action with approximate uniformity over the tuyere zone from which it rises through the coke column, at first being converted to CO_2 , but as it rises from the tuyeres the gas is exposed to an excess of carbon precisely as in a producer bed with the result that the CO_2 quickly breaks down, the additional supply of carbon taking from the CO_2 half its oxygen and reducing the whole to CO. With the blast enters a certain amount of water vapor, and this is instantly dissociated by the incandescent fuel into hydrogen and oxygen, the latter uniting with the fuel exactly as if it entered in the form of oxygen, the hydrogen rising through the lower zones of the furnace as such, but meeting with different fortunes in the upper regions according to the conditions.

We have already seen that the combustion of all the oxygen of the air to CO is complete at the top of the bosh, and as it rises from this point it is progressively exposed to ore containing more and more oxygen, from which the gas progressively removes this element, converting a portion of the CO into CO_2 .

It is well to reiterate here, what I have tried to make clear in earlier chapters, that the ratio of CO and CO_2 in the issuing gases does not depend upon any equilibrium diagram no matter how scientifically derived, but upon the simple arithmetical fact that each unit of ore requires for its final reduction and melting in the hearth a certain quantity of hearth heat, for the production of which a certain definite quantity of fuel is necessary, an amount which can easily be calculated if the conditions are given. This fuel is, as we have seen, burned to CO in the hearth, the unit of ore contains a definite quantity of oxygen, and this quantity of oxygen combining with the given quantity of CO produces a mixture of CO and CO_2 , of

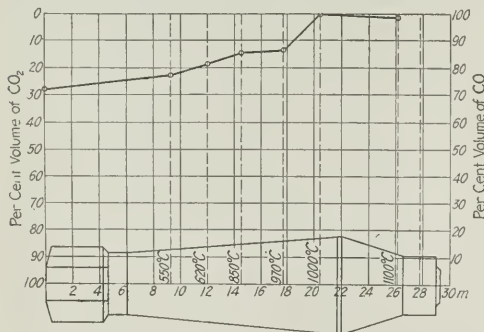


FIG. 1—PERCENTAGE CURVE OF CO_2

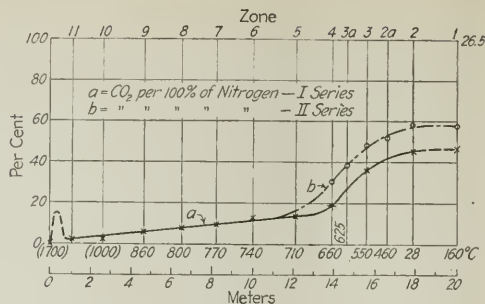


FIG. 2—PERCENTAGE CURVE OF CO

a composition depending purely upon chemical arithmetic, at least within limits far beyond those which we have ever reached. This condition is somewhat modified by the amount of solution loss of fuel which occurs, and this does depend, among other factors, upon the relative concentration of the two gases, but it cannot be too strongly emphasized that the arithmetical relation rather than the chemical equilibrium is the predominant factor in determining the ratio of the top gases.

When we reach a certain point in the furnace the rather slow and orderly change of gas composition takes a sudden turn, the percentage of CO_2 increasing quite rapidly, this increase coming from the CO_2 driven off from the limestone by the heat of the furnace exactly as in a lime kiln.

Figs. 1, 2 and 3 are reproduced from *Stahl und Eisen*, Vol. 31, Fig. 1 from an article by W. A. Schlesinger, Figs. 2 and 3 from one by M. Levin and H. Niedt. These are based upon experimental determinations made by sampling the gas at different heights in the furnace through holes drilled in the wall.

Fig. 2 shows the sudden rise of CO_2 quite plainly, Fig. 3 does not show it, although there is an increase in the rate of rise of the curve in one region, and Fig. 1 shows an absolutely uniform rise of CO_2 , after a sudden increase just above the top of the bosh. These figures are given because of the scarcity of experimental data of this kind, and because experimental data even though they be not representative of our conditions are better than purely theoretical illustrations.

At the same time these curves are all lacking in a strongly marked feature which I found with unmistakable plainness in the course of some experimental work. This is the fact that when CO_2 is driven off from the limestone it at once attacks the carbon vigorously, and a part of it is reduced back to CO so

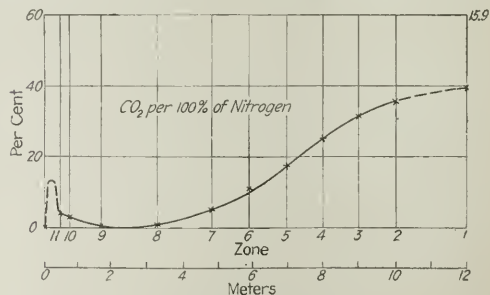


FIG. 3—PERCENTAGE CURVE OF CO_2

that the concentration of CO, at the top of the furnace is considerably less than it is at a point somewhat lower down. This fact was determined by running a 6-in. pipe down through the center of take of a furnace with the Longdale type of top, to a point some 8 or 10 ft. below the stock line, and taking simultaneous samples of the gas discharged through this pipe and that at the top of the furnace. Determinations were made several times, and with a result broadly the same in every case.

This, it must be admitted, is to some extent a contradiction of my statement above that the equilibrium ratio was of minor importance in determining the composition of the top gases, because obviously here we have an established equilibrium disturbed by outside conditions and automatically restoring itself. But my impression is that, as intimated above, this is a matter affecting the solution loss of the coke rather than the equilibrium between the iron ore and the gas composition. It is, moreover, probable that this condition was much more marked in these two furnaces than in many others for three reasons, that the ore was lean, and the quantity of limestone charged, and of CO, disengaged, therefore very large; that the top of the furnace was quite hot, and that the coke was distinctly of a soft and, therefore, readily soluble variety. There can, however, be no doubt that this tendency exists. I believe that the same result has been obtained by other observers sending pipes down from the top of the furnace, but I have no data as to these tests.

TEMPERATURE CHANGES IN THE ASCENDING GAS COLUMN

Figs. 1, 2 and 3 each show a scale of temperatures at different elevations taken through the same observation holes as the gas analyses, but I am unable to accept the temperature given for a point just above the tuyere plane, 2012 deg., as correct, because this is the hottest zone of the furnace and must be at least as hot as the issuing iron and slag which in ordinary coke practice are from 2650 deg. to 2850 deg.

This temperature has been obtained by many hundreds of direct pyrometric observations on issuing iron and slag at several blast furnaces. This is a line of work which has been too little followed, partly because of the lack, until very recent years, of pyrometers of sufficient accuracy to inspire any respect, and partly because of indifference on the part of furnacemen. It is gratifying to note that at the extensive test of titaniferous ore at Fort Henry a pyrometer expert was employed to make observations of the temperature of running iron and cinder, and it is a matter of much satisfaction to the writer that the results of these accurate tests indicated a temperature of about 2800 deg. on this experimental run using all magnetic ore (which requires more fuel and a hotter hearth than softer ores), as against the figure of 2750 deg. obtained by me as the result of many thousands of observations with a much less accurate instrument, a number of years ago, on a furnace working a more reducible, though leaner ore, and almost certainly running with a somewhat colder hearth.

Another reason for mistrusting the data given in Figs. 1 to 3, particularly Fig. 1, is that the drop in temperature from a point just above the tuyeres to the top of the bosh is given as only 100 deg. C. or 180 deg. Fahr., whereas all the facts of practice, above all observations on blown-out furnaces, indicate by the condition of the walls at these points that a far greater difference in temperature between them has existed. For instance, when iron-pipe cooling blocks are used, the cast iron around the wrought pipes is

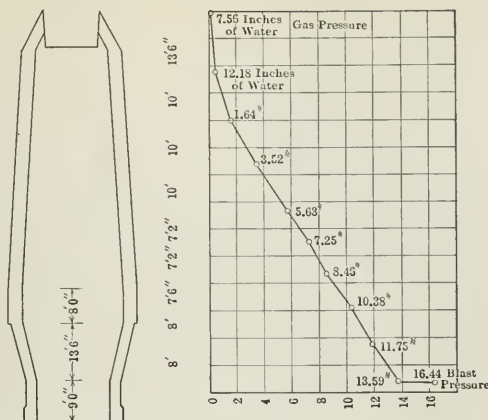


FIG. 4.—PRESSURE TEST ON NO. 4 FURNACE AVERAGE OF 25 READINGS

frequently entirely melted away so that the pipe runs naked in the furnace, in and just above the tuyere plane, while precisely similar blocks at a plane 10 or 12 ft. above are not only perfect in shape, but frequently look when they are taken out at the end of the blast as though they had never been used.

From the top of the bosh upward we have a practically uniform drop in temperature to that at which the gas is discharged, this depending as shown in the last chapter upon the thermal conditions of the operation, the total drop being roughly proportional to the iron produced per ton of fuel.

CHANGES IN THE GAS PRESSURE

Here fortunately all speculation can be laid aside, for owing to the kindness of Mr. Reese I am able to present a diagram, Fig. 4, giving the results of 85 sets of observations of pressure made at holes cut at different levels in one of his furnaces.

There will be seen first a quick drop from the tuyere pressure. This is the penetration drop described in a previous article. From this point on we have a practically straight line drop to a point quite close to the top when the rate of drop slows down, and the curve becomes concave to its base line. This is not due to any change in the law of pressure-drop but merely to the fact that the top of the stock is not a level plane but a conical crater, probably 8 or 9 ft. in depth. The gas pressure begins to be relieved at the bottom of this in the center, but, of course, there is still some resistance and therefore some pressure at the circumference of the furnace at any point below the top of the crater, hence the tapering off in the rate of the drop.

These observations were all made when this furnace was working regularly and properly, but Mr. Reese has also had observations made when the furnace was working irregularly, shown in Fig. 5, and these are equally instructive, if not more so. It will be seen that there are regions in which the pressure drops very rapidly indicating a decided constriction at this point followed by a rate of drop slower than the average, indicating that above the obstruction the gas had ample room to slow down and so reduce the friction drop.

Whether the sudden pressure drop was due to abnormal changes in the charge and produced the irregular working, or whether a partly scaffolded condition produced the sudden pressure drops it is virtually impos-

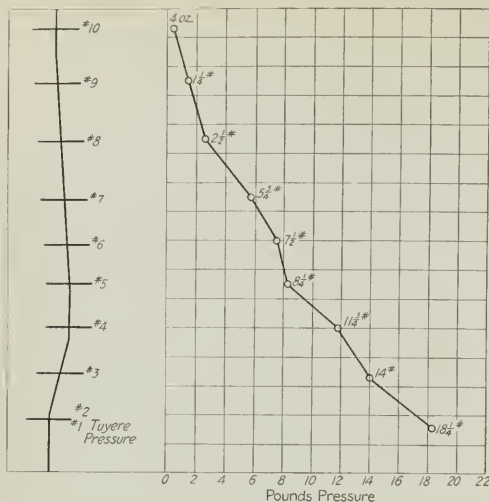


FIG. 5—PRESSURE OF FURNACE MOVING IRREGULARLY

sible to say, but bearing in mind what has been said about the importance of uniform flow of gas, from the practical point of view in cutting down dust losses and the like, the very serious results which must follow from these irregular pressure conditions become obvious, and it is a matter of no surprise that the furnace working under these conditions should produce unsatisfactory results. On the other hand, the extremely smooth curve was obtained as the result of many observations on a smooth working furnace, and its regularity (which must be a matter of surprise to those accustomed to the many minor changes which even a good working furnace makes) indicates that a uniform and regular pressure drop is both the condition and the product of smooth and regular working.

These extremely valuable and interesting results have never before been published and I feel that Mr. Reese has placed not only me but the other members of the profession under a lasting debt of gratitude by so generously allowing their publication here.

SHAPE OF PRESSURE CURVE

The rate at which the pressure drops is a matter of some interest. The shape of the curve of decreasing pressure in a pipe line given by the formula quoted in the last chapter, and established by experiment, is a parabola, the pressure falling slowly at first and more rapidly afterward, just as a horizontally thrown ball does under the influence of gravity. The same should be true of the curve of pressure drop in the furnace because in it as in the other the difference of the squares of the pressures is proportional to the resistance.

Mr. Reese's curve is almost exactly a straight line. One cannot help but wonder if a slight increase in the bosh diameter yielding a lower rate of pressure drop at first, and a proportionately somewhat more rapid one later, would not give a closer approximation to the theoretical parabola, which would correspond with a more nearly uniform velocity, and might easily result in slightly better working for reasons pointed out in the last article.

The spring meeting of the American Chemical Society will be held at Urbana, Ill., from April 18 to 21. That of the American Electrochemical Society at Washington, D. C., from April 27 to 29.

Work on the Federal Trade Commission

The value of technical associations to technical men are well known to most of our readers. That business associations are equally as valuable to business men was brought out in an address by EDWARD N. HURLEY, vice-chairman of the Federal Trade Commission, before the annual meeting of the Rubber Club of America, in New York, Feb. 2, 1916. Mr. Hurley discussed the work of the Federal Trade Commission and showed how the Government could assist business if it had the necessary data. The commission is constantly receiving requests for information on how to improve conditions, and to meet unfair competition. Upon investigation the Commission found that detailed data was nowhere available which would enable them to pass on the underlying difficulties. The Commission in order to co-operate is preparing a few simple questions pertaining to their industries which they will submit to the business men in a few weeks.

Mr. Hurley said the collecting of statistical data could best be done by the Government on account of its facilities and the confidence felt in it by business men. There are about 250,000 business corporations in the country and over 100,000 of these report no net income whatever. In addition 90,000 make less than \$5,000 a year, while only 60,000 make \$5,000 a year or over. In tabulating data on the successful corporations the Commission found that out of 66,000, 30,000 charged off no depreciation whatever and this demonstrated the need of a thorough study of our industries and a necessity for better accounting methods. Price cutting and demoralization of many industries has been done without an adequate knowledge of cost. The Commission hopes to improve conditions by indorsing standard systems of bookkeeping and cost accounting and by assisting in devising standard systems either at the requests of individual concerns or representative associations.

In the field of standardizing products, processes, and raw materials much has already been accomplished. Many industries have adopted specifications to which practically the whole industry conforms. Much of all this has been brought about by associations, but we have made only a beginning. In Germany every important industry is organized into trade associations and 85 per cent of the manufacturers are represented. The old adage "In unity there is strength" is put into practice, and has proved to be the backbone of Germany's industrial and commercial achievements. More than 600 independent associations of manufacturers, producers and merchants are in existence there.

Coming Society Meetings

The American Institute of Electrical Engineers has extended a courteous invitation to the New York Section of the American Electrochemical Society for a meeting on "corrosion" (with special reference to the electrolytic corrosion of underground structures). The meeting will be held on the evening of March 10 in the lecture hall of the United Engineering Societies Building, 29 West Thirty-ninth Street, New York. The two principal speakers will be Dr. Burton McCollum of the Bureau of Standards, Washington, D. C. (representing the A. I. E. E.) and Professor William H. Walker, of the Massachusetts Institute of Technology (representing the A. E. S.).

A meeting of the New York Section of the American Chemical Society will be held on the evening of March 10, in Rumford Hall, Chemists' Club. At this meeting the Nichols medal will be awarded.

A meeting of the New York Section of the Society of Chemical Industry is announced for March 24, to be held in Rumford Hall, Chemists' Club.

The Bureau of Mines Work on Manufacture of Gasoline and Benzene-Toluene from Petroleum

The researches of Dr. W. F. Rittman of the Bureau of Mines, on the production of gasoline, benzene, and toluene from petroleum and other oils have deservedly attracted such a widespread attention that the first complete official publication of the results of this whole series of researches will be exceedingly welcome. It is being published as Bureau of Mines Bulletin No. 114, and is entitled "*Manufacture of Gasoline and Benzene-Toluene from Petroleum and other Hydrocarbons*," by W. F. Rittman, C. B. Dutton and E. W. Dean, with a bibliography compiled by M. S. Howard. From press sheets of this Bulletin the following is taken.

In the preface to the Bulletin some interesting figures on gasoline production are given, taken from a report made by the Secretary of the Interior to the U. S. Senate under date of Feb. 21, 1916, and published as Senate Document 310.

The estimated production of gasoline in the United States for 1915 was 41,600,000 barrels, the amount exported 6,500,000 barrels, leaving 35,100,000 barrels for domestic consumption. The consumption is estimated to have been 25 per cent greater than in 1914. The Secretary of the Interior says the increased cost of gasoline is due to increased domestic consumption, increased exports, decreased production of crude oil containing a large percentage of gasoline, the increase in the price of crude oil and financial influences. The preface states that on Feb. 1, 1916, seven refineries, in six States were installing plants for the Rittman gasoline process, and that benzene and toluene were being produced in large quantities by the other process.

Part I of the Bulletin which comprises 126 pages is entitled "The Cracking of Oils: Principles Involved and Methods of Treating Recovered Products." After taking up the consideration of the present demand for gasoline a historical review of older patented cracking processes is given. This is followed by general considerations on the uses of benzene and toluene and other aromatic hydrocarbons in dyes and explosives and a review of patented processes for their production from petroleum. A complete account of the laboratory experiments made in Columbia University, which led up to the commercial development of the processes is then

given. The results of the experiments led to the following conclusions:

In procuring the desired products of the cracking reaction, the physical and chemical properties of an original oil are of secondary importance compared with the influence of temperature, pressure, time, and concentration.

Under like conditions, practically identical results have been obtained from five different oils, and the differences reported may be attributed, in part, as much to variation in rate of reaction as to the actual production of dissimilar equilibrium products. One exception noted relates to the production of carbon, a residual product, the formation of which seems to be proportional to the quantity contained in the original oil. Viscosities and specific gravities of the oils obtained show in some measure the influence of the properties of the original oils, but the differences are only slight and can perhaps be explained by the system not having been allowed to reach complete equilibrium.

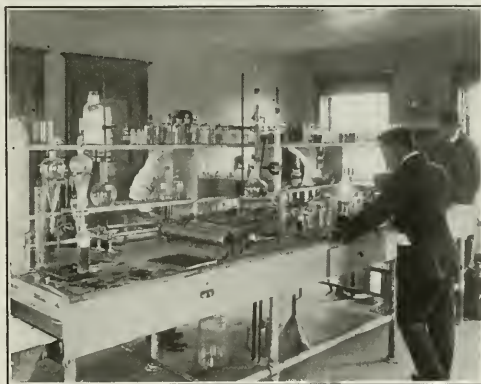
The experiments have indicated the commercial possibilities and advantages of hydrocarbon reactions carried out in a cracking chamber composed of a vertically arranged tube, when the products to be treated are in a gaseous state and are cracked in an atmosphere of decomposition products. The results obtained with large-scale equipment, subsequently described, have demonstrated the correctness of these conclusions.

In connection with these experiments it was also proved that it was possible to make trinitrotoluene from toluene derived from petroleum with as high a melting point and as pure as that from toluene derived from other sources. The method developed was a modification of the two-stage process, producing first mononitrotoluene with subsequent purification and conversion into the trinitro derivative.

Experiments on the cracking of pure hydrocarbons followed by a confirmatory test using petroleum led to the following conclusions: From cymene it is possible to produce by "cracking" all the other hydrocarbons of the series, such as xylene, toluene, benzene, naphthalene,



GENERAL VIEW OF THE IRVINE PLANT, AETNA CHEMICAL COMPANY, PITTSBURGH, PA.



LABORATORY AT DEVELOPMENT PLANT, SHOWING TYPE OF DISTILLATION APPARATUS USED IN TESTING CRACKED OIL

and anthracene. From xylene results toluene, benzene, naphthalene and anthracene, but no cymene. Toluene yields benzene, naphthalene and anthracene, but no cymene and no xylene. Benzene goes to naphthalene and anthracene, but not to any of its higher homologues. From naphthalene anthracene is readily obtainable, but none of the monocyclic hydrocarbons, benzene, toluene, xylene and cymene is produced. Anthracene yields no naphthalene, but goes to tarry matter, carbon and gas.

Likewise it appears that the formation of higher benzene homologues is favored by less strenuous conditions of cracking than constitute an optimum for benzene. Polycyclic hydrocarbons are shown to be decomposition products of monocyclic hydrocarbons, as production of the latter falls off under cracking conditions that favor the formation of such typical compounds as naphthalene and anthracene.

On the basis of the evidence at hand it seems justifiable to state that the course of the cracking reaction in the aromatic series may be indicated as follows and that practically no reverse action occurs.

Higher benzene homologues $\rightleftharpoons$ lower benzene homologues $\rightleftharpoons$ benzene $\rightleftharpoons$ (diphenyl) $\rightleftharpoons$ naphthalene $\rightleftharpoons$ anthracene $\rightleftharpoons$ carbon and gas.

APPLICATION TO OTHER FIELDS OF PRINCIPLES ESTABLISHED BY HYDROCARBON REACTIONS

The technical and industrial importance of these different reactions is much greater than their application to the treatment of petroleum alone would indicate. The principles involved are equally applicable to the treatment of coal, lignite, peat, bitumen, or any other substance capable of yielding liquid hydrocarbons. In fact, the field for application of these principles is even greater as regards these other substances because of their greater extent and production. The output of petroleum in the United States, although 65 per cent of that of the whole world, is decidedly secondary, on

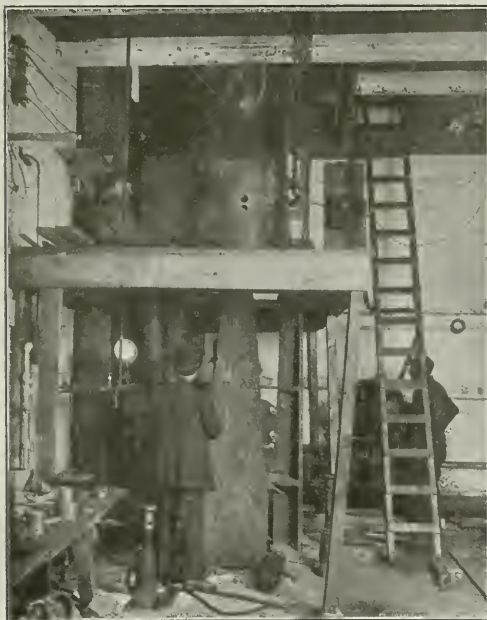
the basis of volume and tonnage, to that of solid fuels, indicating at once the tremendous possibilities in the production of tar and other hydrocarbons from coal and the other materials enumerated.

In view of the widely varying percentages of the different aromatic hydrocarbons obtainable from a crude oil, and in view of the course of reactions among aromatic hydrocarbons, a most significant feature is that there are present in the tars resulting from most present-day distillations of coal a small percentage of low-boiling aromatic hydrocarbons, such as benzene and toluene, and a very large percentage of aromatic hydrocarbons of large molecular weight such as naphthalene and anthracene. The latter undoubtedly are formed in some stage of the operation from monocyclic aromatic hydrocarbons. In practically all coal tars there is less than one part of toluene to three parts benzene. It is furthermore common information that naphthalene, methyl-naphthalenes, methyl-anthracenes, anthracenes, etc., are present in large proportions. In the light of the investigations reported, which unquestionably indicate the course of reaction to be first in the formation of the higher members of the benzene series, then progressively to the formation of toluene, benzene, naphthalene, anthracene, carbon and gas, it is to be concluded that practically every present coal-distillation process carries the cracking to the point of ruinous decomposition of benzene and toluene in the formation of the higher boiling aromatics. The Bureau of Mines is at present investigating this feature.

LARGE-SCALE WORK

The second part of the Bulletin comprising 81 pages deals with the large-scale development of the benzene-toluene and gasoline processes. The following is abstracted from the second part:

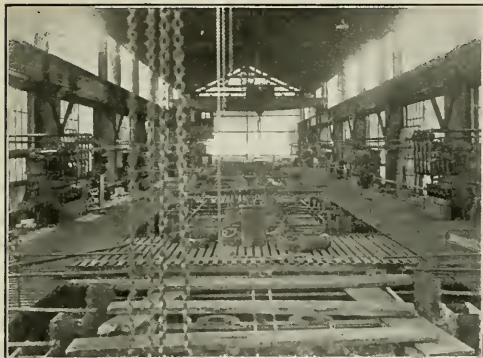
On March 9, 1915, a contract was entered into with the Aetna Explosives Company, who agreed to spend



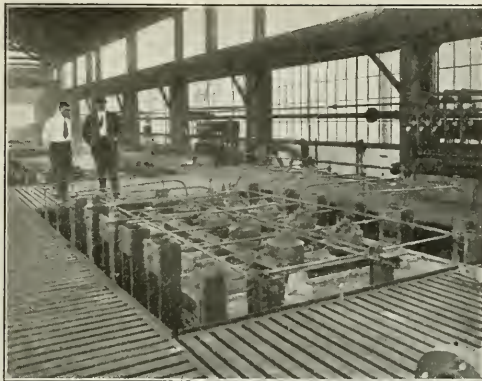
CHARACTER OF SMALL SINGLE-TUBE FURNACES; CONDENSER IS SHOWN IN LEFT FOREGROUND



GROUND FLOOR VIEW OF FURNACE BUILDING, SHOWING ARRANGEMENT AND BUILDING OF FURNACES NOT COMPLETED, AETNA CHEMICAL COMPANY



GENERAL VIEW FROM BALCONY OF OIL PUMPS AND PRESSURE RELEASE VALVES



ARRANGEMENT OF OIL FEED INTO CRACKING TUBES

\$200,000 in the development of the process. Applications for patents on the processes were filed in March, 1915, and it has been decided to have the patents administered by the Secretary of the Interior who will issue licenses to those desiring to use the processes. No royalty or other monetary payments will be required. Although the use of the processes is to be free of charge to all citizens of the United States, it has been considered necessary for the protection of the basic patents, that licensees shall assign to the Secretary of the Interior, as trustee, all patentable improvements, relating to the processes, that may be developed by them during the employment of the process. A provisional form of license has been adopted while the patents are pending. For any information as to licenses application should be made to the Director of the Bureau of Mines, Washington, D. C.

Large-Scale Development of Benzene-Toluene Process

Under the terms of the agreement with the Aetna Explosives Company the work incident to the development of the benzene-toluene process on a scale of commercial magnitude was begun at Pittsburgh, Pa. The engineering firm of Mackintosh, Hemphill & Co. of Pittsburgh, Pa., was retained by the Aetna company for the purpose of developing the mechanical apparatus necessary for the large-scale utilization of the process. Mr. C. C. Stutz was placed by this company in direct charge of engineering matters, under the general supervision of Dr. F. L. Slocum, as representative of the Aetna interests.

EXPERIMENTS WITH VARIOUS SIZES OF TUBES

The original apparatus which was used in the laboratory experiments consisted of a tube $1\frac{1}{2}$ in. in diameter by 3 ft. in length. By many steps it was found that a 6-in. by 10-ft. tube was satisfactory and in harmony with those obtained with other tubes. It was proved that the reaction could be carried on as successfully in a tube of this size as in the much smaller tubes which were first used. But it was evident that the maximum size of furnace body had not yet been found, which suggested the advisability of experimenting with a tube of larger capacity, and tubes up to 14 ft. in length were tried.

From this whole series of experiments it was evident that conversion into low-boiling aromatic hydrocarbons will take place in tubes of any size from $1\frac{1}{2}$ in. by 3 ft. to 8 in. by 14 ft.

Reactions occur as readily in one size of tube as another. The variation in extent of heating surface, however, makes it necessary properly to adjust conditions of temperature, pressure and rate of feed in order to obtain maximum conversion and minimum waste in the form of ultimate decomposition products. The desirable combination of conditions must be experimentally determined for each oil used as original material. It was found that for an 8-in. diameter 14 ft. exceeded the optimum length which could be used, because of the mechanical rather than chemical disadvantages. Likewise it was found that a 7-ft. tube was too short, not because of chemical or mechanical difficulties, but on account of the commercial factor of greatly decreased capacity. The most efficient length for tubes 8 in. in diameter was determined to be 10 ft. (for the heated zone).

A long series of experiments was made with a view of using multiple-tube furnaces instead of single tubes.

Observations of the results obtained in a single-tube furnace as compared with those obtained in 10-tube furnaces demonstrated the superiority of the single-tube over the multiple-tube arrangement.

No difficulty was experienced in maintaining temperature control over the single tubes, whereas it was a constant problem to obtain anything like uniformity of heating conditions with the multiple-tube furnace. To get a uniform heat over a small area of the tube it must be heated on more than one side by burners near one plane. This is not possible in the multiple-tube furnace, but is easy of accomplishment in the single-tube type. One side of the tube in the multiple furnace often becomes too hot and the other side too cold. This would not be the case with the smaller installation.

Separate compartments for each tube would, it is believed, be as satisfactory as single-tube furnaces if sufficient combustion space were allowed. The cost of construction would naturally be less if a number of these compartments were constructed as a unit. It is not recommended, however, that more than four such compartments be arranged in a single unit.

Another recommendation in favor of the single tube is the fact that accurate observation of heating conditions is permitted, which is impossible in the multiple type. With the single-tube furnaces a proportionally much larger combustion space can readily be obtained. The larger combustion space will permit a better mixture of the gas and air and will tend to give more uniform heat conditions, owing to the greater distance the products of combustion must travel before reaching the

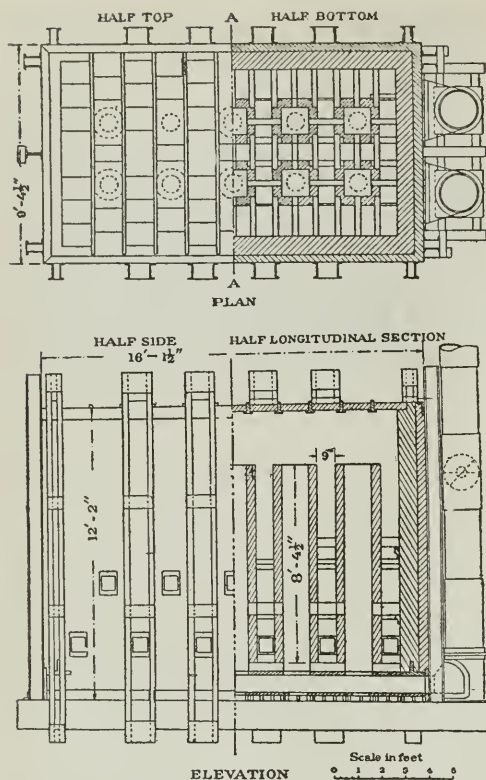


FIG. 1—PLAN AND ELEVATION OF FURNACE

tubes. An outer combustion chamber in which combustion takes place before the gases enter the furnace chamber in which the single tube is set would enable the brickwork in the interior of the multiple furnaces to be dispensed with without any change in the results.

Independent operation of the tubes would permit a tube to be removed or replaced without interfering with the operation of the other tubes. This is difficult in the case of a nest of tubes in a multiple furnace.

Description of Aetna Plant

The details of the furnace construction of the Aetna plant as finally built are given in Figs. 1 and 2, together with the general dimensions of the furnace. The photographs show various parts of the plant.

The furnace proper consists of an outer shell of common brick, lined with a single thickness of standard firebrick. The over-all dimensions of the 10-tube furnace are approximately as follows: Height 12 ft. 5 in., clearance between top and bottom plates 11 ft.; length of sides 16 ft. 1 1/2 in., clearance between inner walls 13 ft. 10 1/2 in., and width 9 ft. 4 1/2 in., clearance between side walls 7 ft. 1 1/2 in. Twenty-two gas burners are used for heating each furnace. Any common type of gas burner of sufficient capacity may be used. The consumption of gas per tube averages about 300 cu. ft. per hour with the present installation, which has not been operated with particular regard to economic heating.

The interior of the furnace is filled with a checkerwork of firebrick. The gaseous products of combustion

pass through a baffle arrangement from the gas ports, ascend through the checkerwork and are drawn inside the chambers of firebrick in which the tubes are placed. From these chambers the gases pass out through two flues at the bottom of the furnace shell and are discharged into the open air through stacks 18 in. in diameter placed at one end of the furnace. The flues are so arranged that the products of combustion of the eleven burners on one side of the furnace pass out through an individual stack. The brick shell of the furnace is strengthened by five steel buckstays on each side and three on each end, these stays being approximately 15 ft. 8 in. high and 8 in. wide. The tops of the stays are connected with tie-rods so as to give greater stability to the furnace. The burners of the upper row are placed at a height of 3 1/2 ft. above the heater platform. It has been found necessary to have a double set of burners in order to supply the additional heat required to maintain the tubes at the desired temperature.

The furnaces are set at a height of 10 1/2 ft. above the ground, and rest on 16-in. I-beams, supported by 8-in. I-beams. The furnaces were thus elevated because it was necessary to place carbon receptacles immediately under the bottom of the tubes, and to rotate the stirring rod from below. The carbon receptacles and the stirring-rod drive rest on concrete foundations.

OIL-FEEDING EQUIPMENT

The general arrangement of the oil feed to the tubes is shown by Fig. 3, which is a sketch of a furnace and its connections. The oil is pumped to the supply tanks, which feed the five tubes on each side of the furnace

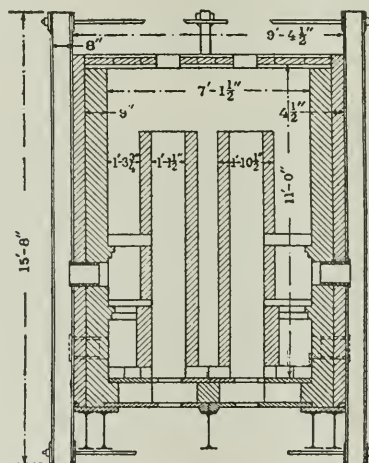


FIG. 2—CROSS-SECTION AA OF FURNACE

and is forced into the tubes by means of triplex pumps, one pump being supplied for each tube.

The oil delivered to each tube by a separate pump traverses a pipe line which is suspended below the upper floor, and thence passes through a needle valve into the top of the tube. The pumps are so constructed that each pump can be calibrated to give any desired rate of flow. The needle valve, which is shown in the foreground, permits independent control of the rate at which the oil is fed into the tube, and enables the oil supply to be immediately cut off in case of accident happening to the tube.

The installation of separate pumps was considered necessary in order to have each tube operated as a

separate unit, notwithstanding the fact that ten tubes were incased in a single furnace.

In the system as installed each tube may be regarded as a separate unit, having no connection with the operation of the other tubes. This type of installation has enabled the reactions occurring in the individual tubes to be carefully studied and has given valuable data which it would be impossible to obtain if the products of all the tubes passed into a single condenser and if a common header were used for supplying oil to all of the tubes.

The individual pumps have served their purpose, but it is not recommended that such a system be used in a new installation. The piping system was so arranged that when the pressure in the tube exceeded the predetermined mark the oil delivered by the pump would be by-passed back into the feed tank.

At first oil meters for measuring the supply fed to each tube were not used, but it was found that the amounts of oil fed into the different tubes varied widely.

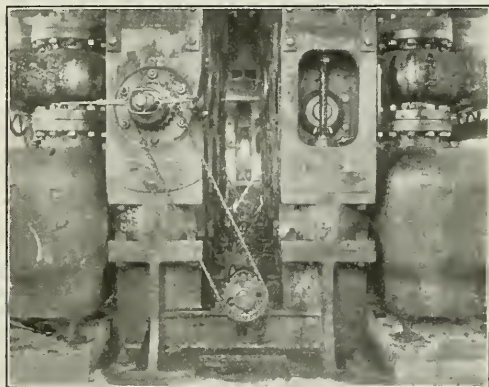
The use of meters has been adopted in order to determine accurately the amount of oil passing into the individual tubes, a meter being installed in each feed line. It has been found that through the use of meters better control and regulation of temperature can be obtained than would be otherwise possible, as the rate of feed can be accurately adjusted to conditions existing in the furnace. It is recommended that oil meters be used in any new installation, as the individual cost of

the meters is small (approximately \$8 each) and the benefits obtained are more than commensurate.

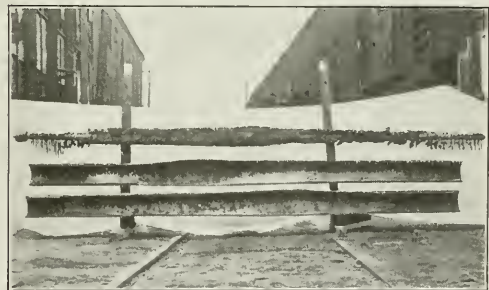
APPARATUS FOR REMOVING DEPOSITED CARBON

The most serious problem that was faced at the outset of operations was the removal of carbon formed on the walls of the tubes. Carbon incrusting on the tube walls acts as an insulator and interferes seriously with the transmission of heat from the furnace to the vaporized oil; also the gradual accretion of carbon diminishes the size of the reaction chamber until the tube becomes entirely choked, which necessitates shutting down the furnace to remove the deposit.

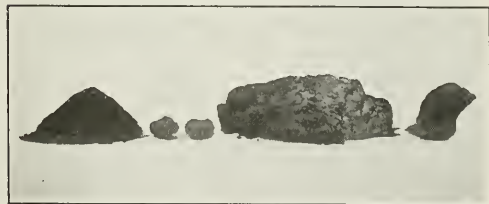
The use of cracking chambers of so large an internal diameter as 8 in. introduces another factor which makes it desirable to use stirrers. In order to heat gases in



DETAILS OF STIRRING-ROD DRIVE



CARBON ON THE STIRRING RODS, OF HISTORICAL INTEREST ONLY. NOW PREVENTED BY IMPROVEMENTS



CHARACTER OF CARBON FORMED IN OPERATION OF BENZENE-TOLUENE PROCESS. THIS IS THE CHARACTER OF COKE THAT RETARDED OPERATIONS IN THE EARLY STAGES OF DEVELOPMENT OF THE PROCESS

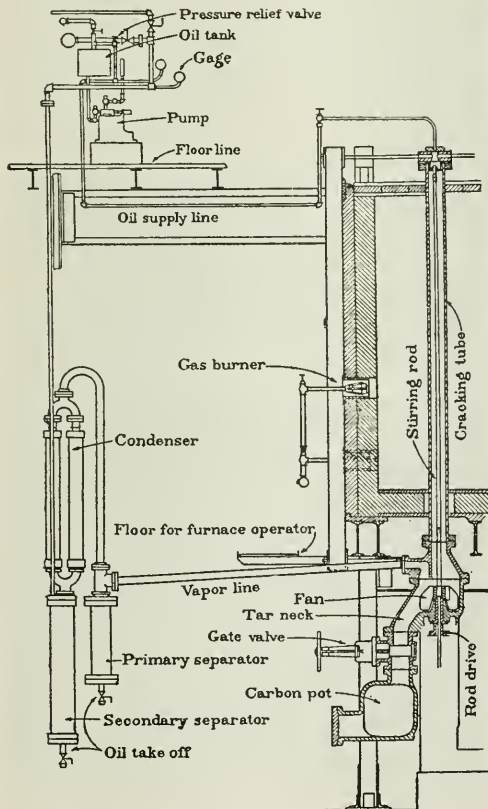


FIG. 3—DIAGRAM OF FURNACE CONNECTIONS



TAR NECKS AND CARBON POTS, SHOWING ALSO ARRANGEMENT OF GATE VALVES

the axis of an 8-in. cylinder to any desired temperature a considerably higher temperature must be maintained at the periphery of the cylinder. One of the advantages of the use of the stirring rod is, therefore, that it makes the cracking chamber annular. Also the stirring action of the rods and chains tends to promote transverse circulation of the gases, which helps to equalize the temperatures.

The use of stirring rods was decided on after careful weighing of the probable advantages of a number of possible devices.

It is apparent that if the rods are continuously rotated in a given direction no means is afforded for cleaning the rod and the chain attached thereto, so that carbon will collect until the accumulation extends to the wall of the tube. The presence of carbon on the surface of the rods and on the chain itself does not, however, interfere with the operation of the apparatus until the amount becomes sufficient to impede the movement of gases through the chamber. When this point is reached the flow of oil into the tube must be stopped and the rod removed and cleaned.

At the outset a rod could be operated only 10 to 24 hr., when the amount of carbon deposition would compel its removal. It has been found possible to increase the length of service to anywhere from 7 to 10 days, with occasional runs of even longer duration.

The use of a rotating rod with wiping chains attached has demonstrated that it will keep the walls of the tubes free from carbon. With the improvements in the construction of this rod which experience has shown to be advisable, and with uniform heat control, it is believed that this type of cleaner can be used with satisfactory results. The great objection, however, to any cleaning device which is permanently retained in the cracking chamber is the fact that although it can be made to clean the walls of the tube there are no means for cleaning it. It is only a question of time, therefore, which in this case means days, before the amount of carbon built up is such as to necessitate the removal and cleaning of the device. Therefore, from a purely mechanical standpoint, a type of cleaner which is not to be permanently retained in the reaction chamber would be more satisfactory, if it cleaned the walls of the chamber equally well. It is entirely possible that a type of plunger cleaner will be found to accomplish this result and obviate the fundamental objection to the use of any intermittent cleaning device, which is the difficulty in obtaining a continuous oil feed and main-

taining uniform conditions of operation. But a plunger cleaner head would be more costly to install and would necessitate detachment whenever a tube was to be removed or its condition examined. Likewise the advantages that accrue from throwing the gases against the walls of the tube would, of course, be largely lost with plungers.

CARBON POTS AND TAR NECKS

The tar neck, so-called, is attached to the bottom of the tube by a flanged head, which is bolted to the corresponding flange attached to the tube. The fixed and the condensable gases, and the carbon which has been removed from the walls of the tube by the mechanical stirrer, pass downward into the tar neck or chamber.

A baffle wall or curtain in the upper part of the chamber around and below which the gases must pass, in order to enter the vapor line leading to the condenser, tends to prevent a large percentage of free carbon from being mechanically carried over with the gases into the condenser. The greater specific gravity of the carbon and pitch causes them to settle rapidly to the bottom of the chamber. (See Fig. 3, p. 273.)

A fan is attached to the vertical shaft which engages with the stirring rod, and is continuously rotated during the progress of a run in order to keep the stirring-rod bearings from being clogged. The action of the fan has a slight tendency also to draw the gases down from the reaction chamber and into the tar neck. The gases, however, being lighter than the heavy pitch and carbon formed, will rise and pass out through the vapor line, leaving the heavy tars and carbon behind.

Carbon receptacles such as those here depicted have the disadvantage of limited capacity. It has been the practice to release the pressure from the tube and to suspend operations while the carbon and pitch were being removed from the carbon receptacle. The duration of the run was fixed accordingly by the capacity of the carbon pot.

The results of the large-scale operations have shown that such massive equipment is not essential. However, this fact could not be predetermined, and it is to the credit of those responsible for the installation that safety has been the first consideration throughout the entire process of development.

The change in the character of carbon formed in the tube from a dense hard coke to a soft flaky carbon, or a heavy viscous tar, has also tended to make the use of large castings unnecessary in the future. If a clean



ENLARGED CARBON POTS USED IN NEWER TYPE OF INSTALLATION

oil is used, such as the distillate to which frequent reference has been made, there is every reason to believe that in place of individual carbon receptacles the tar and carbon can be run from the tar neck direct into a common header and discharged from there into a suitable receiving tank. In fact, provision to this end is now being made at the development plant. If the residuum of recovered oil above the 175 deg. C. cut, or the liquid product from the condenser, is pumped through a suitable opening in the tar neck, there should be no difficulty in causing the carbon and pitch to flow freely through the header. The oil so used can be recovered readily.

The soft flaky carbon is the kind that is formed when proper tube temperatures are maintained throughout a run on Oklahoma crude oil. This soft carbon is usually accompanied by a heavy tar sludge, which is not generally as viscous as that shown in the illustration. Coke is formed when excessive furnace heating occurs. With careful regulation of burners very little of this coke will be produced. The carbon constitutes a valuable by-product and is adapted to a wide variety of industrial uses. It is worth from 1 cent per pound upward, depending on its condition and relative freedom from metallic oxides.

CONDENSERS

At the outset of the experiments it was felt desirable, as previously mentioned, to have each tube operated as a separate unit, thus making it a complete system in itself. This necessitated the use of an individual condenser for each tube. If this plan had not been followed a study of the conversion results in the separate tubes of a single furnace would have been out of the question.

In all new processes a great deal of the equipment considered necessary at the outset can be dispensed

with subsequently. This is the case with the individual condensers. Fig. 4 gives details of the condenser construction.

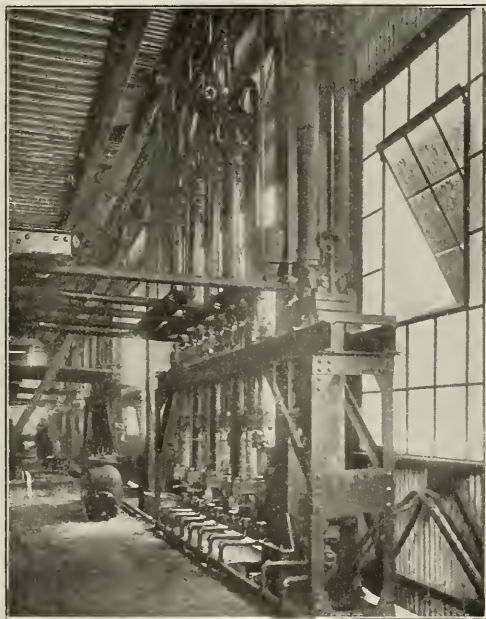
The gases are carried to the condenser through a 3-in. pipe some 12 ft. in length. A receptacle termed the primary separator is connected with the vapor line, in which the more readily condensable liquids are collected. The gases which remain uncondensed at this point pass upward through a 3-in. U-shaped iron pipe into a twin water-cooled condenser consisting of 3-in. copper pipes incased in iron pipes through which water is continually circulated. The liquids which are condensed pass by gravity into what is called the secondary separator. The fixed and uncondensed gases are discharged into a gas header on the upper floor of the furnace building by means of a 1½-in. pipe whenever the pressure on the system exceeds the predetermined pressure.

The primary separator is 8½ in. in diameter by 3 ft. 4 in. in height. The secondary separator is 10½ in. in diameter by 5 ft. 6¼ in. in height. These separators hold as much liquid as will be condensed during a run of the duration permitted by the capacity of the carbon receptacle.

The twin water-cooled condensers are approximately 7 ft. 10 in. in height and have an internal-wall area of approximately 10 sq. ft.

The inefficiency of the condensers, which led to the installation of a large-size condenser and gas scrubber, is shown by the amount of aromatic hydrocarbons in the oil immediately on leaving the condenser and the amount in the same oil after it had been exposed to the air in open barrels, in which it was customary to store it temporarily. It was found that between 30 and 50 per cent of the low-boiling aromatic hydrocarbons formed in the tube had evaporated while the oil was allowed to stand in contact with the air. Some liquid was mechanically carried over by the gases and did not condense in the individual condensers.

The volume of gas formed in the cracking process is



ARRANGEMENT OF CONDENSERS FOR MULTIPLE-TUBE FURNACES

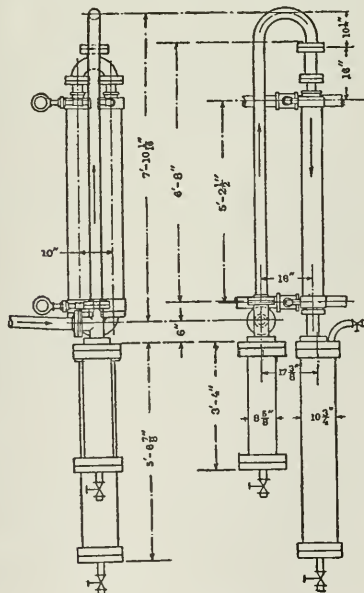


FIG. 4—DETAILS OF CONDENSER CONSTRUCTION

so great that a very considerable percentage of both light and heavy oils is mechanically carried over and does not yield readily to condensation. Traps were placed in the gas line, into which the uncondensed gases were discharged, and analyses have been made for a number of different runs. It was found on distillation from the traps that 50 to 60 per cent boiled over below 175 deg. C., in which cut the benzene content ranged from 5 to 21 per cent and the toluene content from 8 to 25 per cent.

In any new installation for the employment of this process, provision should be made for a condenser of the same type as that used in oil refineries. With the benzene-toluene process, the condensation problem is, however, markedly different from that of the refinery where all the vapors coming from the still are condensable, as in making benzene and toluene considerable volumes of fixed or noncondensable gases are generated. In general a condensing area of approximately $2\frac{1}{2}$ ft. for each barrel of original oil used per day will be found satisfactory if a gas scrubber is operated in connection therewith. This gas scrubber can be modeled after the benzene scrubbing towers in by-product coke-oven plants, or may consist merely of a large tank filled with a heavy oil through which the gases are bubbled. This tank should be so inclosed that the fixed gases can be conducted to a gas holder for the purpose of supplying fuel for the furnaces, if desired. In by-product coke-oven practice the introduction of back pressure by forcing gas through a body of oil would seriously affect the coking products, whereas in the process herein described there is sufficient direct pressure to work against any desired head of oil.

GENERAL DESCRIPTION OF CRACKING SYSTEM IN COMMERCIAL PLANT

The cracking system, both in the benzene-toluene and gasoline processes, is a closed one. Pressure is maintained throughout the entire system while operations are being carried on. The component parts of the system are shown in Fig. 3, in which the various parts are labeled.

The oil is delivered by the pump through the feed line passing under the upper floor, and is carried into the tops of the tubes at a predetermined rate of feed. In the benzene-toluene process the rate of feed is approximately 15 gal. per tube per hour. This rate would be more than doubled in the gasoline process for tubes of the same size. Only a very small quantity of oil is present in the tube in a gaseous form in a given period of time, as a rate of 15 gal. per hour is equivalent to the delivery of only 1 quart of oil per minute. If the oil is preheated, a much higher rate of feed can be attained in both processes.

The oil, upon entering the top of the tube, is spread out over the surface of the basket, which consists of a cast-iron pipe with a perforated top. In the laboratory experiments a basket filled with steel balls was used. These balls were also used in the furnace containing a battery of ten $4\frac{1}{2}$ -in. tubes. It was found, however, that the same results could be obtained by dispensing with the obstructing material and using a spreader of the type mentioned.

The pumps are so set as to deliver the oil under a pressure greater than that in the tubes, so that no difficulty is experienced in causing the oil to flow into the tubes regardless of the pressure employed. The hydrocarbon material fed in is flashed or instantaneously transformed into a gaseous condition and passes downward through what is termed the "cracking zone" of the tube proper, where a temperature is maintained higher than that in the gasification zone. It is in this

part of the container that the heavy hydrocarbons are broken up under the influence of temperature and pressure and in the presence of hydrogen and fixed hydrocarbon gases. Most of the cracking occurs in this zone, although there may be some cracking immediately below the point of gasification. Although not absolutely necessary, it has been found preferable to effect gasification at a point above the cracking zone.

The condensable gases, which are the desired conversion products, pass out of the tube through the tar neck and enter the vapor line leading to the condenser. The gases which remain uncondensed ascend through the gas line connected with the top of the secondary separator and are discharged through pressure release valves either into the open air or into the gas header. The release valve discharging into the open air is used so that in case of any difficulty arising the pressure can be released in the minimum space of time.

The process, however, is not limited to the use of petroleum products, but can be efficiently operated on liquid hydrocarbon material derived from any source. Solvent naphthas, and light oil distillates from water-gas tars and coal tar have been successfully used. These light oils and solvent naphthas are extremely favorable for use in the process as yields two to three times larger than those obtainable from petroleum products can be had in a single operation. The petroleum oils, however, give a wider range of by-products. This fact, together with their greater availability, as well as lower cost, probably render them most suitable for use. Wherever supplies of the distillates from coal or water-gas tar are available in quantity, they are a most prolific source of benzene and toluene. If such distillates were procurable in the open market their use would be highly profitable at a time like the present (1915), when both benzene and toluene are commanding heretofore unheard-of prices.

The great advantage in the use of light-oil distillates from coal and water-gas tars, aside from the greater yields obtainable, is the fact that diminished pressure can be used. Vacuum or atmospheric pressure has been shown to give results as favorable with these oils as higher pressures.

The experiments have clearly indicated that the vapor-phase cracking process is not limited to any particular type of oil, and that an asphaltic oil, a paraffin-base oil, oil having a paraffin and asphaltic base, and certain oils obtainable from the destructive distillation of coal, are all suitable for use in the process.

The combustion chamber in the multiple-tube furnace contains approximately 1100 cu. ft. of space or an average of 110 cu. ft. per tube. This combustion volume seems to be insufficient for the best results under the conditions of operation which have existed during the period covered by this report. It is believed, however, that much better results could be obtained with this volume of furnace per tube if it were to be combined with an efficient outer combustion chamber.

In the operation of the plant a laborer, termed a heater, is employed for each furnace of ten tubes. This man has charge of the 22 burners required to heat a single furnace, and is engaged constantly in the regulation of the burners in order to maintain the required temperature. This regulation of heat is controlled by optical determination of the temperature, as judged by the condition of the tube and brickwork in the interior of the furnace. Pyrometers have also been used, but have given results of varying character.

Pressure in the cracking system is maintained by controlling the discharge of the gases formed by the decomposition of the hydrocarbons fed into the tube. In the operation of the process at the development plant

a laborer is employed for each unit of five tubes in order to regulate the pressure. Regulation is accomplished by opening a valve and permitting the gases to escape into a gas main or header until the pressure in the individual tube has been sufficiently lowered to keep it at the point required.

When as large a quantity of benzene as possible is desired the pressure used was 250 lb. per square inch. When it was desired to obtain more toluene a pressure of 150 lb. was used.

As was stated in the discussion of temperature, carbon difficulties increase when heat is not uniformly regulated. The experiments again indicated the already well-known fact that the percentage of carbon formed increases with temperature.

The presence of carbon in the reaction chamber is a disadvantage from the mechanical side alone. From various references in the appended bibliography it can be discovered that carbon is one of the best catalysts for the formation of benzene and toluene.

It is evident from the development of the process that formation of carbon in the cracking tube is not an obstacle to the operation of the process when control conditions are in proper relationship. Too low a rate of feed at a moderately high temperature will cause higher percentages of carbon to form. Excessive temperatures and pressures will likewise promote excessive carbon formation, but when these factors are in their proper relationship the character of the carbon is such that little or no difficulty is encountered in its removal.

Plain lap-welded tubes have not proven entirely satisfactory. A small number of lap-welded tubes that were calorized (coated with aluminium) by the General Electric Company have been in operation for several weeks. The results to date of writing have been entirely satisfactory, especially as less carbon trouble has been experienced with these tubes than with like tubes not calorized.

Based upon experience extending over a period of seven months, it is recommended that either rolled or cast steel tubes be used in lieu of lap-welded tubes. The walls of the tubes should be not less than 1 in. thick for maximum efficiency in operation.

The benzene-toluene process produces more than enough gas for continual operation of the cracking furnaces. Regardless of the character of oil used, 40 to 50 cu. ft. of fixed gases is generated for each gallon of oil cracked.

Very small amounts of gas are produced in the gasoline process as compared with the benzene-toluene process, consequently either natural gas, oil, or some other form of fuel would have to be employed to heat the cracking furnace.

Up to the time of writing no opportunity has been afforded for the detailed study of that part of the recovered oil distilling above 175 deg. C.

It is difficult to give cost data for a unit plant for either the gasoline or benzene-toluene process. Although several plants are being projected for 1916, only one plant has been constructed during the period for which data have been given. This installation is the one owned and operated by the Aetna company. The conditions under which this plant was erected were such as to make the costs unusually high. Consequently it would not be fair either to the company or to the process to quote such figures. Also their quotation is inadvisable.

The cost of a gasoline plant will be considerably less than that of a benzene-toluene plant, as little or no carbon is formed and elaborate equipment for the removal and reception of this substance is not required; also a gas scrubber and a gas holder would not be needed, as

the volume of fixed gases generated in making gasoline is small.

Large-Scale Gasoline Production

Opportunity has not been afforded for testing the gasoline process on a large commercial scale, as is the case of the benzene-toluene process. The inability of the Department of the Interior to accede to the requests made for exclusive rights, or for recoupment of expenses incurred in the development of the gasoline process, has prevented reaching an understanding. At the time of writing licenses have been issued to four refining companies, each of which is about to install small experimental units.

The Aetna Explosives Co. has been most courteous and obliging in extending facilities for conducting gasoline tests in the single-tube furnaces, during such times as the use of the furnaces could be spared for this purpose. Accordingly a considerable number of runs were made in the single tubes with the different oils available. Three oils were used in the experiments, one was a fuel oil from Pennsylvania-West Virginia crude petroleum and the other two were distillate oils, one having a boiling point ranging between 250 deg. and 350 deg. C., and the other between 200 deg. and 300 deg. C.

Experiments were made with a 6-in. by 9-ft. tube and with an 8-in. by 10-ft. tube. The average percentages of gasoline recovered were low, being 18.8 per cent and 21.5 per cent with the 6-in. by 9-ft. tubes using two distillate oils and 19.5 per cent with the 8-in. by 10-ft. tube using distillate oil. An average recovery of 24.3 was obtained with a distillate fuel oil in the 8-in. by 10-ft. tube but the average percentage of recovered oil was lower.

In considering the figures obtained, it must be remembered that efficient condensation was lacking. The work was carried on during intervals when benzene-toluene experiments were being conducted with equipment erected to obtain indications as to benzene-toluene reactions, and not to determine maximum yields. Accordingly the condensing facilities were of the crudest type. The results can be considered only as suggestive of what can be accomplished under proper conditions. Viewed in this light they are of a distinctly favorable character, and justify optimistic belief in the large-scale commercial possibilities of the process.

GASOLINE PROCESS COMPARED WITH BENZENE-TOLUENE PROCESS

In comparison with the benzene-toluene process, the gasoline process is simple in character. This may be more readily perceived by considering the order of hydrocarbon reactions as given below. The relative order is not only based on theory, but is in accordance with the evidence gained as the result of extended series of tests.

The order of the reactions is as follows: heavy petroleum hydrocarbons $\rightleftharpoons$ light petroleum hydrocarbons (saturated and unsaturated) $\rightleftharpoons$ cymene $\rightleftharpoons$ xylene $\rightleftharpoons$ toluene $\rightleftharpoons$ benzene $\rightleftharpoons$ naphthalene, diphenyl, etc., $\rightleftharpoons$ anthracene, $\rightleftharpoons$ carbon and gas.

The conversion from heavy hydrocarbons into lighter hydrocarbons involves only one step, and is easy of accomplishment, whereas the conversion into the lower boiling aromatic hydrocarbons requires that the heavier hydrocarbon molecules undergo a much more extensive series of changes before the desired products are obtained. This difference will indicate why the mechanical difficulties experienced in the first stages of development of the benzene-toluene process are non-existent so far as the gasoline process is concerned. The lower

temperatures necessary and the greatly decreased quantity of carbon produced eliminate serious trouble from overheating and clogging in gasoline manufacture.

Because of the greater ease with which gasoline can be made the installation used for benzene-toluene production will have double the capacity when used for conversion of heavy oil into gasoline. The duration of the gasoline reaction is less than half that required for the benzene-toluene reaction if the same size and length of tubes be used. It is manifest, therefore, that by introducing twice the volume of oil to be converted, the effect will be the same as decreasing the time factor by one-half.

The installation if used solely for gasoline production can be materially changed in many respects. The expensive carbon receptacles can be done away with, and the height of the furnaces above the ground materially reduced, thus lowering the cost of furnace construction.

The large-scale experiments have fully confirmed the laboratory experiments and established the fact that the conversion into gasoline can be even more satisfactorily accomplished in a tube of greatly enlarged diameter and increased length than in the electrically heated 1½-in. tube. The conditions favorable for gasoline production are shown to be the same in the larger tubes as in the small tube, namely, a temperature of approximately 500 deg. to 575 deg. C. and a pressure of 250 to 300 lb. per square inch.

The gasoline process, therefore, can justly be considered as a success so far as conversion in the large tubes is concerned. The adaptation of the unit to refinery conditions is a matter of mechanical detail involving no inherent difficulties.

Early in September, 1915, the Department of the Interior was advised by the Aetna Explosives Co. that the plants were completed for the production of explosives from benzene and toluene obtained by the process of cracking in the vapor phase. In accordance with the express understanding between the company and the bureau, this necessitated the severance of the co-operative relations existing. This understanding was had to obviate any objection due to the utilization of Government employees in work involving the preparation of explosives.

Synopsis of Recent Chemical and Metallurgical Literature

Gold and Silver

Metallurgy of Native Silver Ores of Mexico.—In a paper presented at the second Pan-American Scientific Congress, Washington, D. C., Mr. W. M. BRODIE discusses the treatment of native silver ores occurring in Chihuahua, Mexico. Ores of this type were worked at Batopilas before 1632, by methods of sorting and cobbing together with smelting in crude forms of reverberatory and blast furnaces. At the present time the silver is recovered by concentration, amalgamation, cyanidation and smelting. The enriching of the ore begins in the mine, where pains are taken to separate high and low-grade material.

The high-grade ore is fed by hand to stamps, the fine passing the screen and the coarse remaining in the mortar. The latter is removed and washed by hand, after which it is ready for refining. The stamp discharge which has passed a 30-mesh screen, is treated in amalgamation pans with 0.5 per cent cyanide solution, and as soon as the grinding is completed mercury is added to collect the metallic silver. The pan tailing is discharged to a settler and thence to a Dorr thickener and Pachuca agitator, being treated in the last machine with 0.5 per cent cyanide solution. The amalgam, which

may contain from one-third to one-half silver, receives the usual treatment, and the retort silver runs about 950 fine.

Low-grade ore assays from 10 to 20 oz. silver per ton, depending on its proximity to high-grade deposits in the mine, but is usually of 10-oz. grade. This is concentrated on tables of the Bartlett and Wilfley types, the tailings containing about 2 oz. silver per ton. The concentrates are re-concentrated and separated into two grades, one containing 3000 to 7000 oz. per ton and the other from 200 to 400 oz. A third-class concentrate of about 100 oz. may be obtained, and the tailing usually carries between 8 and 9 oz. per ton. The ratio of concentration is about 50:1.

The first-class concentrate is treated in an amalgamating pan with cyanide solution and mercury, and is reduced in value to about 30 oz. per ton. It is then added to the other pan tailings in the Dorr thickener. The second-class concentrate is cyanided by percolation together with the coarse settlings from the settlers in which the pan tailings are washed after amalgamation. The silver leaches slowly but without difficulty.

The silver is precipitated on zinc shavings in the usual manner, and the precipitate is filtered and dried in a cast-iron retort. It is then refined together with the stamp-mill silver and the pan silver in a reverberatory furnace of the Freiberg type. The pan and stamp-mill silver are charged first, and when the contained silica floats on the charge, the cyanide precipitate mixed with about 5 per cent borax glass is added. In this way a fairly fusible slag is made and skimmed. If the bath is kept at the proper temperature there is no great loss of silver by volatilization.

Slags from refining are ground and sifted to recover metallic silver, which is then treated in an amalgamating pan with cyanide solution and mercury in a manner similar to that used for high-grade concentrates. This avoids by-products and cleans up the operation quickly.

Copper

Leaching at Chuquicamata, Chile.—The metallurgical methods employed by the Chile Exploration Company in treating the copper ores at Chuquicamata, Chile, were outlined in detail in this journal May, 1914. Since that time the proposed methods have been put in successful operation, and some data from practice are given by Mr. C. A. ROSE in a paper presented at the second Pan-American Scientific Congress, from which we abstract the following:

The ore is leached in 10,000-ton concrete vats, and the first solution is applied by upward percolation in order to avoid an accumulation of fine ore at the bottom of the vat. This solution is allowed a contact of from thirty-six to forty-eight hours, when it is withdrawn and replaced with solution acting by downward percolation. The following extract from a report sheet will show the cycle of treatment:

LEACHING OPERATION SHEET									
Charge No. 41 Tank No. 5		Date charged, Oct. 9, 1915 Tonnage, 8,212 met. tons							
Date	Solutions Put on				Solutions Drawn off				
	Cu.	M.	Copper	Grams per Liter Acid Chlorine	Cu.	M.	Copper	Grams per Liter Acid Chlorine	
13	3.300	34.8	68.0	1.9					
17	2.560	21.7	69.5	0.7	2.700	47.8	38.0	4.9	
18	2.050	25.0	50.4	0.6	2.320	42.1	52.0	3.0	
	3.275	36.4	43.6	2.8	3.312	36.3	48.0	2.1	
	3.225	30.7	32.8	2.8	3.312	35.4	43.1	2.5	
	3.375	21.6	19.6	2.4	3.275	30.9	32.8	2.6	
	3.287	7.9	6.4	1.0	3.300	22.1	19.1	2.3	
	Water 600 tons				2.800	11.2	7.5	1.1	

A part of the last solution withdrawn in each cycle is removed for complete deposition of copper, after which it is discarded. The solution thus removed compensates for the increase in volume due to the addition

of more water in the last wash than is discharged as moisture in the residue, and also removes continuously certain impurities that otherwise would accumulate in the solution. These impurities consist of sulphates of sodium, potassium and magnesium, which are in no way detrimental to the process. They accumulate until the circulating solution contains about 150 grams per liter of sodium sulphate, 10 grams potassium sulphate and 65 grams magnesium sulphate, after which the discarded solution removes the same quantity at each cycle as is introduced by the ore. Iron sulphate does not accumulate rapidly, amounting to only 3.4 grams per liter after treating forty-five charges of ore. Some nitric acid exists in the ore, due probably to nitrates blown from adjacent nitrate beds. This acid is prevented from accumulating by the discard of solution. Chlorine is removed in the dechloridizing plant, where the solution is passed through tube-mills containing granulated copper. This precipitates cuprous chloride, which is separated by filtration. Various methods of treating this cuprous chloride have been tried—by smelting, electrolysis and cementation. The last process is indicated as the most suitable, due to the need of securing cement copper for the dechloridizing tube-mills. The method of treatment is dissolution in brine and precipitation on scrap iron. The consumption of iron is less than half that usually found in treating copper solutions, since the copper is in the cuprous state and practically no free acid is present.

Magnetite anodes were first used for electrolytic precipitation, but owing to the impossibility of securing these from Europe on account of the war, duriron has been substituted with success. This material is a silicon-iron alloy, and while not wholly unacted upon by the solutions, from fifteen to twenty times its weight of copper can be deposited before the anode is entirely corroded. Duriron anodes have an advantage over magnetite in their mechanical strength, but a disadvantage in requiring about 15 per cent more electrical energy for the deposition of the same quantity of copper. The purity of Chuquicamata copper is somewhat higher than that derived from American electrolytic refineries; its conductivity is from 100.5 to 101 per cent, Matthiessen's standard.

Metallurgical Methods of the Braden Copper Co.—Two recent publications give interesting data on copper concentrating and smelting at Sewell, Chile, the scene of operations of the Braden Copper Company. In a paper presented before the second Pan-American Scientific Congress, Messrs. R. E. DOUGLASS and B. T. COLLEY, respectively concentrator and smelter superintendent, describe the development of the entire plant at Sewell. Until the advent of flotation, concentration was effected by the usual gravity methods, using Harz jigs, tables and buddles. The recovery of copper in concentrate was not high, and even after an improvement to the original plant it remained low. Minerals Separation flotation process was installed and has resulted in greatly increasing the saving. Originally the froth from the tailing compartments of the machines was retreated in another plant, but this method has been superseded by returning the free-running froth from the last compartments to the head of the same machine. The tailings from Minerals Separation machines are treated by air cells, both rougher and cleaner types.

The reagents used in flotation are Swedish or American pine-tar oil, fuel oil, sulphuric acid and a small amount of kerosene to thin the fuel oil. A part of the pine-tar oil is added at the Hardinge mills and the balance at the head of the flotation machines. A sulphuric acid plant is operated intermittently as needed.

The first smelting plant consisted of agglomerating

or sintering apparatus and a small blast furnace. Owing to excessive loss of sulphur in the sintering operation, the large percentage of fine ore and high operating cost the agglomerating process was not a success. In the second smelting plant the concentrates were briquetted and smelted in a blast furnace, since local conditions made the use of the customary reverberatory inadvisable. There was no difficulty in briquetting the concentrates by the addition of clay, but the concentrate was already high in silica and alumina and called for extraneous flux to form a slag. Limestone was scarce and cost \$12 per ton. The components of the charge were briquet concentrate, converter slag and limestone. The converter slag was easily fused and the sulphides in the briquets quickly melted and separated themselves from the gangue, leaving in the furnace a difficultly fusible skeleton of silica and alumina. Later the flotation plant began operations and imposed a new set of conditions on the furnaces. The flotation concentrates were very fine and easily fusible, but being excessively wet they blanketed the charge and greatly increased the coke consumption. In order to improve these conditions further experiments in down-draft sintering were initiated and a good product was finally made. Still later experiments showed the feasibility of nodulizing the concentrates, all kinds of the latter being treated. The result was the adoption of nodulizing kilns, advantage being found to lie in long kilns of large diameter. The latest type is 100 ft. long and 9 ft. diameter. The smelting of nodules has proved successful and in accord with usual blast-furnace practice, and the fuel consumption dropped to 8 per cent per ton of charge.

In the company's monthly publication, *Teniente Topics*, the following data are given relative to smelting: The concentrate contains 19 per cent copper, 17 per cent silica, 23 per cent iron, 2 per cent lime, 8 per cent alumina and 28 per cent sulphur. Of 350 tons of this material, recovered from 4000 tons of ore, about 215 tons is nodulized, 50 tons is sintered on grates, and 85 tons is smelted raw. The matta resulting from smelting the mixture of nodulized, sintered and raw concentrates contains about 45 per cent copper, and is converted in Pierce-Smith basic-lined converters.

Lead and Zinc

Preferential Flotation of Galena and Blende.—The Australian *Mining and Engineering Review* gives a description of the separation of galena and blende at the works of the Sulphide Corporation, Broken Hill. In this plant the Minerals Separation machines have been superseded by the Hebbard-Harvey under-drive machines, and the capacity is about 4000 tons per week. The flotation plant handles tailings from the lead mill, where the largest part of the galena is separated. These tailings carry 4.2 per cent lead and 18 per cent zinc. The pulp is first agitated with eucalyptus oil, and the froth carries 57 per cent Pb. The residue assays 3 per cent Pb and 18.5 per cent Zn. In the next flotation treatment oil and acid are used, and the concentrate assays 6 per cent Pb and 47.5 per cent Zn. The final tailing assays 1 per cent Pb and 2 per cent Zn. The process is conducted in the cold and effects the recovery of an additional 15 per cent lead and silver as compared with the process previously in use. Another important factor in this separation is that the new process may permit the fine tabling in the lead mill to be discontinued. Rhodonite forms the principal obstacle to successful tabling, as its specific gravity is between that of galena and blende. Flotation, however, gets rid of rhodonite as well as of other gangue matter, and makes possible an easier separation of the two minerals in subsequent tabling operations.

Iron and Steel

Vacuum-Fused Silicon-Iron.—In a paper in the February issue of the *Bulletin* of the American Institute of Mining Engineers, T. D. YENSEN of the University of Illinois, gives the results of his experiments on vacuum-fused iron containing varying percentages of silicon. The experiments were made in an attempt to improve the iron used in dynamo-electrical machinery. The qualities desired were low hysteresis loss, high electrical resistivity (to reduce eddy-current loss), and high permeability. Previous experiments by the author had shown that pure electrolytic iron, melted and cooled in vacuo, possessed desirable properties in respect to high permeability (about twice that of the best commercial iron) and low hysteresis loss. If the electrical resistivity of this iron, which in the pure state is very low, could be increased without impairing its magnetic properties, an excellent iron for electromagnetic purposes would be produced. Previous experiments by Prof. C. F. Burgess at the University of Wisconsin had shown that when melted in an atmosphere of carbon monoxide at ordinary pressures pure iron absorbed about 0.1 per cent carbon and probably some oxygen as the electric resistance increased more than would be expected from the carbon alone. The iron used in the present experiments was doubly refined electrolytic iron deposited from Swedish charcoal iron according to the methods of Burgess (see this journal, Vol. II, May, 1904). The refined iron had the following composition: carbon, 0.006 to 0.01 per cent; silicon, 0.01 per cent; sulphur, trace; iron (by difference), 99.98 per cent.

The experiments were made in a vacuum furnace modeled after the Arsem type (see this journal, Vol. IV, page 223, June, 1906), and a Geryck pump was used capable of maintaining a pressure of 0.5 mm. of mercury or less with 500 grams of molten iron in the furnace. Previous experiments by the author had shown that carbon and boron when alloyed with this vacuum-fused iron lowered the magnetic quality and they were thus undesirable where high permeability and low hysteresis were needed. The present experiments with silicon gave opposite results and seem to have produced an iron which possesses very remarkable properties highly desirable in iron for electrical machinery. Before being used the iron was crushed, cleaned with hydrochloric acid, water and alcohol and dried by means of ether in vacuo. About 600 grams of this cleaned iron was then placed in a fused magnesia crucible together with the desired portion of the alloying element, covered with a magnesia cover and placed in the vacuum furnace where it was melted under a finishing pressure of 0.5 mm. of mercury. The ingots, after being allowed to cool in the furnace, were heated in an ordinary coke forge and forged into rods about $\frac{1}{2}$ in. (1.25 cm.) by 20 in. (50 cm.) under a steam hammer. No contamination took place in this operation. From these rods the test pieces were prepared; one rod 14 in. (35.5 cm.) long for the magnetic and electrical tests; two test pieces, $2\frac{1}{2}$ in. (6.3 cm.) long, with threaded ends, for mechanical tests; and one small specimen for the metallographic investigation. Magnetic and electrical tests were made and photomicrographs were taken after the following heat treatments:

- As forged.
- Annealed at 900 deg. C. Cooled at a rate of 30 deg. per hour.
- Annealed at 1100 deg. C. Cooled at a rate of 30 deg. per hour.

Mechanical tests were made as forged and after annealing at 970 deg. C. A few specimens were annealed at 1100 deg. C. The annealing was done in vacuo so as to preclude any possible contamination by gases, the

vacuum part of the furnace used for this purpose consisting of an "electroquartz" tube with mercury-sealed ends.

The results are summarized as follows:

By means of the vacuum method of melting it is possible to obtain a decidedly purer product than has thus far been obtained in any other manner. Consequently by the use of this method more definite conclusions than have hitherto been possible can be drawn with regard to the effect of silicon upon iron.

Silicon, like boron, has a double effect upon iron. Part of it combines with the iron and remains in solid solution throughout the cooling of the alloy, while a smaller part reduces the iron oxide present.

The tensile strength of the vacuum product follows in general the same law as alloys made under ordinary conditions, but the ductility of the former is much greater, particularly below 2 per cent and above 3 per cent, probably due to the absence of carbon. The maximum tensile strength of 105,000 lb. per square inch (73.5 kg. per square millimeter) occurs with a silicon content of 4.5 per cent.

The limit of forgeability lies between 7 and 8 per cent silicon. A critical range occurs between 2.50 and 2.60 per cent, in which the alloys are exceedingly brittle, in some cases being not even forgeable. The chemical composition of the latter corresponds to a compound of the formula Fe_2Si .

With regard to the magnetic properties, the vacuum alloys exhibit most remarkable characteristics. The best alloys are obtained with about 0.15 per cent, and 3.40 per cent silicon after annealing at 1100 deg. C. The maximum permeability for both of these alloys is above 50,000, and the hysteresis loss for $B_{\text{max}} = 10,000$ and 15,000 is about 300 and 1000 ergs per cubic centimeter per cycle respectively. This hysteresis loss is 1.8 and $\frac{1}{3}$ of the corresponding loss for commercial silicon steel. The most favorable annealing temperature is in every case 1100 deg. C.

The specific electrical resistance increases about 13 microhms for the first per cent silicon added. For each additional per cent added the increase is about 11 microhms. Consequently the 3.40 per cent alloy mentioned above has a resistance nearly five times that of the 0.15 per cent alloy.

By the vacuum process two silicon alloys have thus been produced that have very valuable characteristics; one low in silicon, not very strong, but extremely ductile, of high permeability, low hysteresis loss, and of low electrical resistance; the other high in silicon, very strong, moderately tough, of high permeability, low hysteresis loss and of high electrical resistance. The properties for these two alloys are summarized in Table I. The first is evidently suitable for use in places where high permeability and low hysteresis loss are the chief requirements, while the second alloy is suitable for electromagnetic machinery, principally transformers, where a low eddy current loss is an additional requirement.

TABLE I.—PROPERTIES OF THE TWO BEST IRON-SILICON VACUUM ALLOYS

Silicon Content, per Cent	Strength Yield Point, Lb. per Sq. In.	Ultimate Strength, Lb. per Sq. In.	Elongation, per Cent	Reduction of Area, per Cent	Maximum Permeability	Density for Max. Permeability, Gausss	Hysteresis Loss, Ergs c.c. Cycle		Spec. Elect. Resist- ance, Microhms
							For $B_{\text{max}} =$ 10,000	For $B_{\text{max}} =$ 15,000	
0.15	18,500	37,000	56	90.0	Above 50,000	6,500	286*	916†	11,800
3.40	55,000	76,500	21	28.5	Above 50,000	6,500	280*	1,025†	48.5

*From data recently obtained with rings these values may be 10 to 20 per cent low.

†From data recently obtained with rings these values may be 5 to 10 per cent high.

Recent Chemical and Metallurgical Patents

Iron and Steel

Regenerative Furnace.—A regenerative furnace for open-hearth steel practice, which uses pulverized coal, forced draft, and may be placed above the open-hearth furnace proper and within the same walls, is patented by JOHN E. BELL of New York City. The arrangement of the regenerator is shown in Fig. 1. Air is blown in through 7 from a blower, and passes through the successive parts of the right-hand generator, *a*, *b*, *c*, and *d*, respectively, when the valve is arranged as in the drawing. At the same time pulverized coal is fed in at 17*a*, in separate combustion chamber 5*a*. The falling coal and preheated air unite and the coal burns forming a producer gas, which passes under 14*a* and up through 3*a* to the hearth of the furnace 2. The ash of the coal falls on grate 15*a* where steam or steam and air is introduced to aid in consuming any unburned

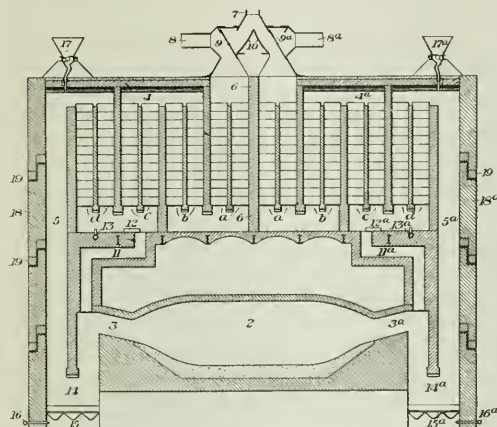


FIG. 1—REGENERATIVE FURNACE

carbon and prevent the formation of clinker. The gases pass out at 3 and up through chamber 5, to second regenerator 4, and thence through 8 to the stacks. When reversed the coal is stopped at 17*a* and is fed in at 17 in the other side.

A secondary combustion may be effected by introducing auxiliary heated air through passages 11, the amount regulated by check damper 12. Steam may be admitted at 13 and 13*a*, to regulate temperature of regenerator or water tubes may be inclosed in the furnace walls to take up some of the heat. This regenerator may also be placed alongside of or below the furnace proper. Straight, smooth passages are made in the regenerator which take 2000 to 4000 lb. of gas per square foot of flue area per hour as compared with 500 lb. average in ordinary practice.

The advantages claimed for this combination are a considerable economy in fuel, a low stack temperature, and efficient combustion with long controllable flame. An advantage is claimed in having the regenerator inclosed as a unit with the furnace and in using blowers which give, on account of the high velocity, a sort of eddy or mixed flow to the gases similar to smoke coming out of a stack, whereby a better heat transfer is made. (1,170,397 Feb. 1, 1916.)

Valve Mechanism for Regenerative Furnaces.—A valve mechanism for shutting off the gas supply and stack draft during the reversing operation is patented by LOUIS N. McDONALD of Youngstown, Ohio. During

the reversing of the gases in the regenerative firing system some gas escapes into the chambers which escapes unconsumed to the stack when the valve is completely reversed. In order to prevent losses of this kind it is proposed to connect two sliding valves in the flues, one to shut off the flow of gas and the other the stack draft during the reversing operation. These are suitably connected to the reversing valve and are operated with this valve. With both the gas inlet flue and the stack flue closed, the gas remaining in the checker work will flow into the furnace during the reversing of the valve. Another advantage claimed is that an increased pressure will accumulate behind the gas flow valve, which will fill the checker chamber quickly when the valve is opened. (1,170,301 Feb. 1, 1916.)

Method of Producing Aluminothermic Mixtures.—In making aluminothermic mixtures in the thermit process it has been customary to add 15 to 20 per cent of constituents additional to the aluminium and oxide in order to temper the reaction and to alter the composition of the resulting metal. In order to make it possible to add more than 20 per cent of additional constituents without lowering the temperature of the reaction too much, and thus reduce the cost of operation, a method is patented by JOHN H. DEPPLE of Jersey City, N. J. (assigned to Goldschmidt Thermit Co.). In this method the additional constituents are placed in a separate container (which will melt when heated to welding temperature) and preheated by the waste gases from the torch used in heating up the sections to be welded. This container when preheated to a red heat is then placed in the aluminothermic mixture in the reaction crucible and melts together with that mixture in the mold in which the welding operation is carried on. (1,168,061, Jan. 11, 1916.)

Manganese

Colloidal Manganese Dioxide.—Colloidal manganese dioxide used as a depolarizer for miniature batteries used in pocket flashlights is patented by CARLETON ELLIS of Montclair, N. J. The process of making this material is as follows: Five parts of glucose are dissolved in twenty parts of water and cooled in ice. Four parts of a 10 per cent solution of caustic soda is added and then 100 parts of a 5 per cent solution of potassium permanganate is added little by little while cooling the mixture and stirring. The mass stiffens after this addition, in a few minutes, to a jelly and on standing this begins to contract and break up into blocks with separation of liquid. This is facilitated by heating. When forming the colloidal manganese around particles of mineral or artificial manganese dioxide, the above operation is carried out in the presence of this material. The depolarizer has the property of compacting to a firm mass which can be handled without breaking. (1,169,943 Feb. 1, 1916.)

Phenol

Retort for High Pressures and Temperatures.—A retort for producing synthetic chemicals "such as phenol, alpha naphthol, toluene, creosote, pyrocatechin, and other carbon compounds of similar nature, alkalis and hydrochloric acid, etc.," where high temperatures and pressures are desired is patented by JOHN R. WATSON of Baltimore, Md. This retort consists of a high-pressure metal tube with contracted ends, having on its outside electric heating resistances insulated from the body of the retort. Through one end of the retort is placed a thermocouple for automatically controlling the temperature through suitable electrical connections with the heating resistances. On the other end, which is the feed and discharge end, is

a special cap which screws on and which has within it a stem with cone-shaped end which fits into the end of the retort. When the temperature rises to a certain point this stem (which is made of a metal with higher coefficient of expansion and lower melting point than the retort), expands and helps to seal the retort. Should the temperature and pressure go too high, this stem would become soft and allow of an escape into the outer portion of the cap, giving warning and preventing an explosion. (1,169,893 Feb. 1, 1916.)

Electric Furnaces

Electric Furnace for Gas Reactions.—An electric furnace for carrying out gas reactions as patented by ALOIS HELFENSTEIN of Vienna, Austria-Hungary, is shown in Fig. 2. This furnace permits of the intimate association of solid, liquid and gaseous material and catalyzers may thus be used and secondary products also obtained. Gases which it is desired shall react are introduced through pipe 1, through electrode 3, entering a molten bath 7 which is contained in the conducting bottom 6, forming the other electrode. Above this bath is a granular resistance or reacting material with which the gases commingle and then pass into chamber 8, where condensing agents are introduced through nozzles 9. They then pass through flues 10 into connecting chamber 11.

Examples of reactions which may be carried out are given as follows: 1. Acetylene and nitrogen to hydrocyanic acid. Slag bath of clayey earth with floating granular charge of animal coal or charcoal as contact material. 2. Production of carbon tetrachloride by introduction of chlorine into mixture of charcoal and sulphur vapor. Sulphur chloride is first formed, then acted upon by the carbon to form sulphur and carbon tetrachloride. The sulphur may be either absorbed by a silicate slag bath or recovered in the vaporous state. 3. Combining of silicon and nitrogen to form silicon nitride. A quartz bath, over which is a layer of carbon for reducing silica to silicon is used. Nitrogen passed in through electrode. (1,169,817 Feb. 1, 1916.)

Carbon Electrode Production.—A process of making carbon electrodes in which the gases formed are burned and used to heat the furnace is patented by FRANZ NAGELSCHMITZ of Munich, Germany (assigned to Georg Mendheim of Munich, Germany). In this process the coal or coke and tarry binder for making the electrodes are heated in a furnace with a longitudinally extending channel above it for conducting away the gases. The gases pass out of the furnace through a flue into another flue which is also connected to the heating chambers of the furnace surrounding the working chamber. The gases pass from this latter

flue back into the heating passages of the furnace where they are mixed with hot air and burned. The furnace produces the heating gas necessary for its operation. The electrodes are prevented from oxidizing by the use of a packing medium of petrol-coke. (1,170,313 Feb. 1, 1916.)

Metallurgical Furnaces

Calcining, Desulphurizing and Agglomerating Ores.—In two patents granted to FRANZ MEYER of Uerdingen, Germany, and by him assigned to Dwight & Lloyd Metallurgical Co., of New York City, the inventor discloses the structure of a furnace for roasting and sintering ores in a continuous operation. The principle of the furnace is similar to that used in the Dwight-Lloyd straight-line sintering machine, viz., forming a layer of ore on a grate, igniting its surface and inducing a down-draft through the mass. In the present instance the furnace consists of an annular grate rotatable about a central mast, the latter being hollow and communicating with the several grate compartments by radial conduits through which the gases of combustion are drawn off. The individual compartments beneath the grate surface are formed by annular plates dipping into a water seal and by cross-partition plates similarly dipping into a water seal. In operation, the charge is fed continuously onto the moving grate from a hopper. At a certain point the charge is ignited when passing under a source of heat. Combustion is sustained by drawing air downward through the charge as the grate revolves. The quantity of air thus drawn is regulated by spring valves in the conduits running from the grate compartments to the central mast, the spring valves, in turn, being actuated by traveling over an annular cam-track. The elevations in the cam-track can be so placed and of such magnitude as to regulate the draft, by allowing the valves to be open wide or practically closed. At the charging section of the grate the cams are so high that the valves are practically closed, and similarly at the point of discharge. The latter operation is effected by a plow scraping the sinter from the grates. (1,162,634 and 1,166,142, Nov. 30 and Dec. 28, 1915.)

A desulphurizing furnace patented by LEWIS B. SKINNER of Denver, Col., is illustrated in Fig. 3. The object of the construction is to secure an improved draft system, whereby the gases will be removed from

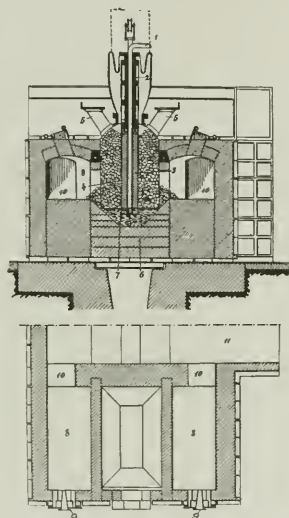


FIG. 2—ELECTRIC GAS REACTION FURNACE

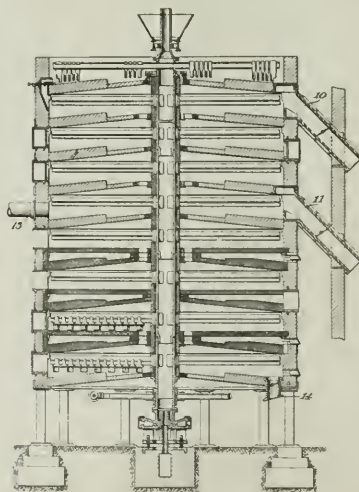


FIG. 3—ROASTING FURNACE

the furnace with as much heat as possible, thus making them more useful for subsequent purposes, as for the manufacture of sulphuric acid. Another object is to construct a furnace that will avoid the generation of excess heat in the middle hearths, thereby injuring the structure. The furnace is of the superposed hearth type, with a central revolving shaft carrying the rabble arms which sweep over the ore on the hearths and cause its movement from hearth to hearth downward through the furnace. As shown in the figure, the three lower hearths are hollow, or of the muffle type. In order to prevent overheating in the middle hearths, special arrangements are made to vary the draft through the furnace. Thus two outlets for gas are shown at 10 and 11, the former at the topmost hearth and the latter opposite a middle hearth. Intakes for air are provided at 13 and 14, the former at a middle hearth and the latter at the bottom. The amount of air admitted and gas leaving the furnace can be regulated by dampers in the outlets and intakes. The result of this arrangement is that there is a uniform temperature throughout the various hearths of the roaster, and the hot gas in the middle zone is removed with all its heat. In a second patent granted to the same inventor means of radiating heat through the furnace walls are provided in the form of steel or iron plates inserted into recesses in the wall of the furnace. Instead of plates, jackets adapted to air or water cooling may be inserted. (1,164,131-2, Dec. 14, 1915.)

Cerium and Alloys

Cerium Used in Alkaline Storage Battery.—A patent has been issued to THOMAS A. EDISON of West Orange, N. J. (assigned to Edison Storage Battery Co.), for an alkaline storage battery in which the positive element is made up of alternate layers of nickel flake and a cerium compound. The material is prepared as follows: A solution of a soluble salt of cerium such as the sulphate is treated with caustic soda and the precipitate is washed and dried and ignited to a white heat in an atmosphere of hydrogen and then cooled down in hydrogen. The product is finely divided and probably consists of an oxide or mixtures of oxides of cerium. For the negative elements of the battery finely divided iron or iron oxides are preferably used. An electrolyte of potassium or sodium hydroxide is used, having added to it a small percentage of lithium hydroxide. (1,167,485, Jan. 11, 1916.)

Gold Alloys.—Alloys intended to be used as substitutes for certain platinum and palladium alloys are patented by KARL G. P. RICHTER of Pforzheim, Germany (assigned to Dr. Richter & Co. of Pforzheim). The alloys are made by substituting a metal of the iron-nickel group, particularly nickel for metals of the palladium group. In this way alloys are obtained which are not much different in cost from the ordinary gold alloys, while the brittleness produced by the nickel is removed by the combination of the nickel with the noble metal. The alloy is malleable and may be used in jewelry manufacture. Instead of pure gold, copper-gold alloys may be used as the starting material. (1,165,448, Dec. 28, 1916.)

Ductile Alloys of High Melting Point.—Alloys for use in electric lamps, firearms or as tools and instruments for various purposes are patented by HANS KAISER of Augsburg, Germany (assigned to Wolfram-Lampen Aktien Gesellschaft of Augsburg, Germany). These alloys are produced by selecting a metal such as tungsten as a base and adding two additional metals before sintering, the first additional metal, such as thorium, consisting of about 1 per cent, and the second

additional metal, such as platinum or a metal of the platinum group, being added in very small proportion, i.e., about 1/20 of 1 per cent. The addition of the third metal increases the toughness and ductility and reduces the sintering temperature. (1,167,827, Jan. 11, 1916.)

Counter-Migration of Pulp and Solution in Cyanidation and Acid Leaching

BY BERNARD MAC DONALD

CYANIDATION

Since "all sliming" has been adopted as the most desirable condition, generally speaking, to which an ore should be reduced in order to obtain the best results in cyanide treatment, the efforts of metallurgists have been directed largely to the improvement of the plant apparatus, and of the methods previously used for the agitation of the slime and for the separation of the solution from the leached-out "barren" solids in the treated pulp.

Fig. 1 indicates the means by which these essential objects are automatically secured, and the counter-

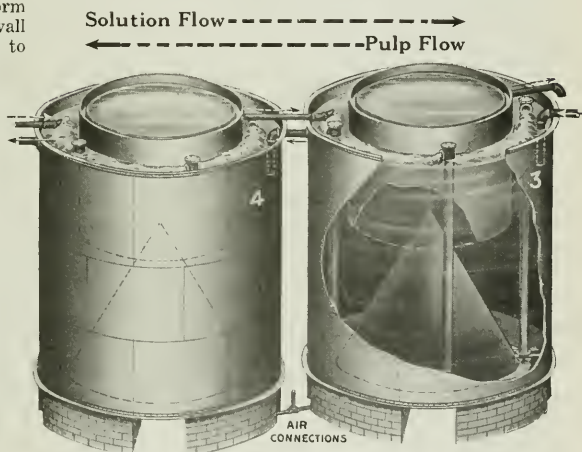


FIG. 1—COUNTER MIGRATION

migration of the solution and solid constituents of the pulp effected in a series of Parral tanks.

The equipment specially instrumental in bringing about these objects consists of a circular diaphragm, water-tight at the sides, open at the top and bottom and supported centrally in the upper portion of the tank. This diaphragm extends vertically down below the pulp level to a certain depth designed to meet conditions, which, for this description, is assumed as 8 ft., and above the pulp level to the height of 2 ft. In this position the diaphragm divides the upper position of the tank into two areas, the annular space between the side of the tank and the diaphragm known as the "agitation circle" and the space inclosed within the diaphragm known as the "separatory area."

The solution and solids in the pulp to be treated may be in any suitable ratio, but for a definite description the usual 2:1 ratio is assumed. In this ratio the pulp contains two parts of solution to one of solids by weight, which gives it a specific gravity of 1.26, or about one and a quarter times the weight of the same volume of water.

In operation the pulp to be treated flows in a continu-

ous stream through a feed pipe which delivers it in the agitation circle two or three feet below the pulp level where it is merged with the pulp in agitation there.

The agitation of the pulp is effected by the mechanical means peculiar to the Parral tank system.

Four transfer pipes, each 6 in. in diameter, are set at quarter points in the tanks, their lower or intake ends reaching within a few inches of the tank's bottom, and their upper or discharge ends emerging about 4 in. above the pulp level. The discharge ends of these pipes are fitted with tees or ells with their discharge openings directed so as to discharge in the same direction around in the agitation circle. Half-inch pipes connecting with the compressed-air main outside the tank are fixed centrally within the transfer-pipes and terminate in a ball-nozzle-valve at a point about 5 in. above their lower ends. Compressed air having a pressure of say 10 per cent higher than the static pressure due to the pulp depth in the tank is introduced through this connection into the transfer pipes which are operated as air lifts. In operation the transfer pipes throw continuous streams of pulp, transferring it from the bottom and delivering it on the top of the tank charge. The spouting force of these streams discharging in the same direction at the surface of the pulp mass in the agitation circle sets up and maintains a rotary flow in the pulp which extends from top to bottom of the tank.

This flow and the continuous withdrawal of the pulp from the bottom of the tank and its redistribution over the surface of the tank charge, gives it the required aeration and keeps its solution and solid constituents in proportionate mixture, a condition which is essential for the effective dissolving out of the metals in the solids.

While the agitation of the pulp is going on in the agitation circle the area within the diaphragm remains absolutely quiet, with the result that the solids settle rapidly out of the contained pulp and sink to the bottom of the tank, there coming within the suction range of the transfer-pipes, they are transferred to the surface where they are carried away in the rotary flow. As the solids settle out of the solution within the diaphragm the clear solution remains in hydrostatic balance with the denser pulp in the agitation circle. This pulp, as above stated, having specific gravity of 1.26, will balance a column of clear solution one and a quarter times its own height. Therefore, the 8-ft. column of pulp outside the diaphragm will raise the clear solution to a height of 10 ft., or 2 ft. above the pulp level in the agitation circle. At the height of 7 ft. 6 in. on the inside of the diaphragm is fixed an annular launder, into which clear solution rising within the diaphragm overflows continuously. From this launder a pipe conducts the clear solution over the top edge of the tank, and delivers it into the agitation circle of the next tank adjoining where it becomes mixed and agitated with the pulp and is again separated from it as above described.

As the solution is thus migrating from tank to tank in each of which it is mixed and agitated with new pulp flowing in the opposite direction, it dissolves out and takes up the metals contained in the solids and thus becomes richer while the solids become poorer as they pass from tank to tank. When the solution is separated from the head tank of the series it is sent to the precipitation room where the values held by it are precipitated and the solution, now barren, is returned to the tail-end tank of the series, where it begins again its migration through the tank series, repeating the same effect above outlined.

The tail end of each series of treatment tanks consists of two tanks used for the settlement of the pulp and decantation of all the solution possible from the pulp before it is discharged to the filter or dump. The

equipment of these tanks is similar to the others, but the pulp is received alternately in them, which allows of intermittent settlement, decantation and agitation by which all the solution consistent with flowage is removed from the pulp.

The volume of compressed air consumed in operating the transfer pipes is very small, owing to the fact that the pulp is transferred through them from the bottom to the top of the tank charge under practically hydrostatic balance—a lift of only 4 in. above the pulp level being required. The volume of the streams of pulp transferred may be regulated to any quantity desirable by the valves on the compressed air pipes.

ACID LEACHING

The method of agitation and the counter-migration of the pulp and solution above described is applicable and especially advantageous in the leaching of copper ores by sulphuric acid solution. In this treatment of copper ores the methods are analogous, almost identical with cyanidation, except that the solution being acid requires acid proof apparatus for the agitation of the pulp and the manipulation of the solution.

For copper leaching the Parral tanks and all their equipment are made of wood and are unaffected by the acid solutions. The almost complete separation of the metal-laden solution from the leached-out pulp that is possible to make in Parral tanks by the method described, which obviates the necessity of filtering—the most difficult part of acid leaching—makes this method of treatment worthy of the serious consideration of those engaged in the hydrometallurgy of copper ores.

Los Angeles, Cal.

Paper Thread and Cloth

A Substitute for Cotton

The war has shut off a great many raw materials from Germany which are needed in her industries. This has forced her to invent new materials which suit old purposes but are made from raw materials which can be procured at home. In many ways the ingenuity of the German chemists has manifested itself. One industry which has received attention for this reason is that of paper thread and cloth; it has become important because the cotton supply was practically shut off. A summary of this industry is given in the *Zeitschrift des Vereins Deutscher Ingenieure* Jan. 8, 1916, by W. HEINKE. These products have been made in Germany for a number of years without a very general knowledge nor broad application. The paper and textile industries are responsible for their production, and the process is based on Japanese processes in use for 100 years.

The raw materials used are wood cellulose, sawdust, old paper, rags, rope, or waste from the cotton, jute, flax and hemp spinning industries. These are made into paper, and this paper is then cut into strips by machinery and twisted into thread or used untwisted as a substitute for jute thread and cotton thread in linings, carpets, sacks, and other material. The Japanese have for a long time used paper cloth for various purposes, but it remained for Germany to develop machines for cutting and spinning, and create a good-sized industry. At present the cellulose used is mostly from pine and cypress.

A modern strip cutting machine for cutting the paper into strips can cut (according to the makers) 3000 kilograms of paper stock in 10 hr. in strips up to 10 mm. width. Only one workman is needed for this machine. After cutting, the strips are moistened and spun into thread on the spinning machine, which may be of several different types.



FIG. 1—TWISTING OF DRY PAPER STRIP

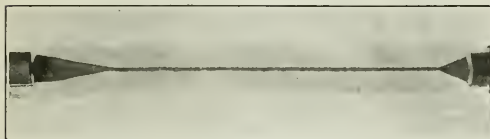


FIG. 2—TWISTING OF MOISTENED PAPER STRIP

It is necessary to moisten the strips before spinning, otherwise they will crumple and tear and will not stand the spinning. On the other hand they must not be made too moist, otherwise their strength will be impaired. In Fig. 1 is shown a dry paper strip in the process of turning, which is probably ready to tear. Fig. 2 shows a moistened paper strip spun into a thread. The spinning must not be carried too far or the paper will naturally tear.

The cutting machines are usually of the revolving cylinder type, the paper stock passing between two cylinders. On the upper cylinder the knives are placed, spaced according to the width desired and fitting into grooves on the lower cylinder, the knives being held fast to one edge of the groove. After cutting the paper, it is either wound on spools or is moistened and conducted directly to the spinning machine. For moistening it is run over a cylinder which is moistened by another cylinder touching it and passing through a tank of water below its axis.

The spinning machines have reached quite a high degree of perfection and are described in some detail with illustrations in the original article. They all accomplish the same purpose, but differ only in mechanical details. An improved machine, known as the plate-spinning machine and manufactured by Aktien Gesellschaft Karl Hamel in Schönaue, is shown in Fig. 3, and will give some idea as to the extent that this industry is being developed in Germany.

The microscope has come into use in observing the tensions at different stages of the spinning. Practical colors can be produced on the woven fabric by chemical means, and the paper cloth has found considerable use in covering threads of jute, flax, and cotton, giving them a smooth appearance, and covering up loosely spun threads which would make them rough. Unraveling is also prevented, and in the packing of goods with jute this is of considerable value. Metal wire is also covered

with this paper material. The paper thread is also woven with textile thread, and the product not only possesses the outward appearance of textile goods, but is also more firm.

Quite a number of machines have been patented in Germany during the last year for the covering of thread and wire by spinning paper thread over it. Machines have also been devised for covering paper thread with textile thread, and the various uses to which this paper seems to be applicable are evidently unlimited.

By different means it has been tried to make the paper thread waterproof for application in special fabrics. As a result of the war, which produced a shortage of jute and cotton thread, this question is important and a means will probably be found for waterproofing paper threads. For binding twine as well as for sacks the paper thread finds considerable use. The paper thread gives them a certain firmness along with flexibility. The paper thread is not spun to obtain a great firmness as in common textile spinning, but chiefly to give it a round form with the flexibility. Paper threads tested by the author gave strengths on stretching five to six times that of the original paper strip.

As a rule the same twisting frame can be used for weaving paper cloth as for weaving textile cloth. Cloth going by the trade name of "textilose" is a combination of paper and cotton or jute, the cotton or jute usually glued on both sides of the paper. "Textilin" is made by folding and pressing paper strips by a special machine instead of spinning them.

Factories and private experimenters have been quietly working for ten years on the problem, and it is expected that the industry will reach large proportions. From this side of the Atlantic it would seem that the boom of this new industry has been caused by the present shortage of cotton in Germany. Yet necessity is the mother of invention, and many times a new industry has only begun to flourish after the peculiar economic conditions which brought it into existence have ceased to exist.

Development of a Modern Ball-Mill

The use of ball-mills for grinding ore is probably adapted from the cement industry, where such mills were most successfully used for fine grinding of the clinker. Perhaps an earlier use of similar apparatus can be found in the familiar "rattler" of the foundry, which is used to clean castings of various sizes by allowing them to tumble over each other in a revolving cylinder.

The simplicity and efficiency of this type of grinding apparatus has led to its wide adoption in ore treatment, where it has found favor over other forms of grinding apparatus. In its earlier use, in the form commonly known as the tube-mill, flint pebbles were used as the grinding medium and the lining was made of siliceous blocks. Other forms of lining have been developed, such as the El Oro, in which the pebbles become wedged between iron bars and thus become the lining. The tube-mill is essentially a long cylinder, having a length of from 4 to 4½ times the diameter. Considerable discussion has centered on the requisite length of such mills, many authorities contending that practically all the efficiency of the tube was found in the first few feet from the feed end, and that nothing of consequence in the way of further grinding was accomplished near the discharge end. This has led to the shortening of the tube, thereby reducing the first cost and lessening the power requirement. In at least one case that has come to notice this contention regarding the efficient grinding zone in the long tube-mill seems to have been

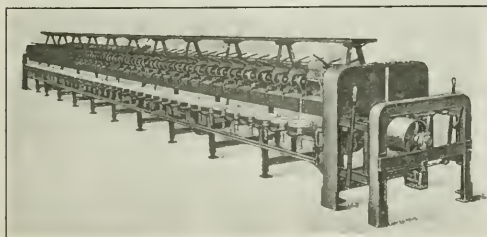


FIG. 3—PLATE SPINNING MACHINE

established. The tube was $4\frac{1}{2}$ ft. by 18 ft. After being in service for a long time it became leaky, so that pulp discharged at various points along its length. The operator collected samples of the pulp thus discharged, and on making screen analyses of the discharge at various points along the length of the tube he found that practically no efficient grinding was done in the last 14 ft.

Probably the first ball-mills successfully used were made by Krupp of Germany, and were applied in dry crushing. These mills had a screen at the periphery outside of the liners, the latter being so arranged that when the ore was partly ground it would emerge through openings which were somewhat larger than the screen openings that determined the size of final product. That portion of the material that did not pass through the outside screen re-entered the grinding portion of the mill.

The next development of any consequence was Hardinge's conical mill, which, instead of having a cylindrical grinding chamber, is composed of two cones with their bases attached to a short cylinder. One of the cones, at the feed end, is shorter than the one through which the pulp discharges. A high efficiency is claimed for this mill, due to the selective action of the pebbles or balls used for grinding, whereby the larger balls or pebbles remain in the center of the mill and grade to smaller sizes toward the discharge. As the ore particles tend to arrange themselves in similar manner, the larger balls or pebbles work on the larger pieces of ore with intermediate gradations down to the smallest pebbles and smallest particles of ore. Thus it is sought to apply energy as needed in accordance with the size of ore particles.

In this type of mill, however, as with all tube-mills which discharge their products at about the same level with the feed, we have a selective action giving a classified product in which a fine particle of heavy mineral is discharged with a larger piece of light gangue. Since the minerals in an ore are frequently softer than the accompanying gangue, this action may have the effect of grinding mineral finer than is necessary, especially where crushing and grinding are being done for subsequent ore-dressing and not for sliming as in cyanidation.

An earlier type of ball-mill, which in some respects embodied the ideas of the latest types, was known as the Ferraris. It was on the market for a time, but owing to a defect in design which will be pointed out later it did not come into wide use. This mill is illustrated in Fig. 1. It consisted of a revolvable drum divided into two compartments, *A* and *B*, by an annular perforated partition *a*. The larger or crushing compartment *A* was lined with ribbed steel plates and contained forged steel balls varying in size from 3 to 6 in. The smaller or screening compartment *B* was divided into a series of pockets by means of radial partitions extending from a cone *b* that projected back into

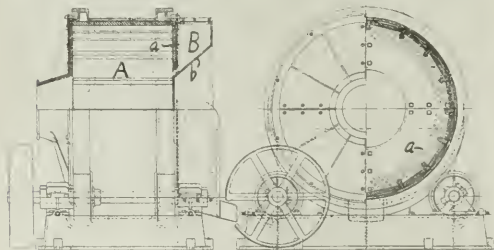


FIG. 1—FERRARIS BALL-MILL

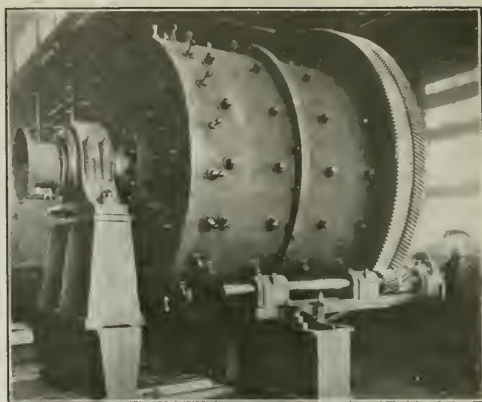


FIG. 2—MARCY BALL-MILL

the crushing compartment. The periphery of the screening compartment was open and surrounded by a screen of the desired mesh. When the ore was ground fine enough to pass the perforations of the annular partition it flowed into the screening compartment and out through the peripheral screen into a housing surrounding the lower part of the compartment. That portion which was not ground fine enough to pass the screen was elevated by the radial partitions in compartment *B* and slid back on the surface of the cone into the crushing compartment *B*.

In the light of later experience the failure of this mill to perform as expected was due to the fact that the oversize was returned at a point where there was little or no chance for further grinding. Had the entire pulp, after passing the annular partition, been screened outside the mill and the oversize returned at the feed end, there would have been effective regrinding; but when it was returned to a point just inside the annular partition there was no opportunity for further grinding, as the oversize immediately short-circuited through the partition and accumulated until the mill was choked. Nevertheless the Ferraris mill may be regarded as the forerunner of the modern short ball-mill, embodying as it did the perforated partition with low discharge and

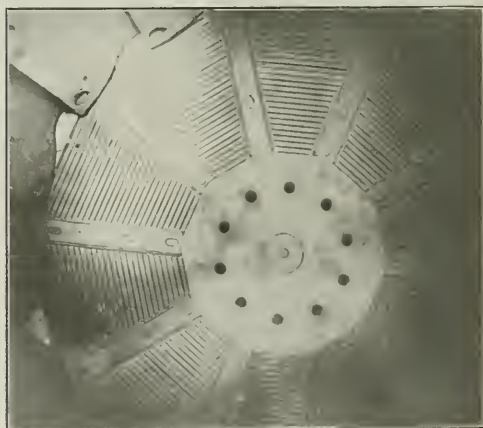


FIG. 3—ANNULAR GRATING AND LINING MARCY BALL-MILL

the radial lifters. But for the failure to recognize the necessity of outside screening and return of oversize at the feed end, we might have had the modern short ball-mill years ago.

In the development of the modern short ball-mill we endeavor to provide a crushing machine in compact form that will take feed up to 3 or 4 in. in diameter and reduce it to, say from 10 to 60-mesh, according to requirements, in one operation, the product being screened or classified outside the mill and the oversize returned with original feed. The grinding medium is steel balls and the lining is of such form as to provide a series of steps or corrugations which lift the charge as the mill revolves. This has the effect of causing the ore and balls to cascade, the former being crushed by impact of the latter. Early experience with such mills showed that they were efficient grinders, but when used with trunnion or overflow discharge on practically the same level as the feed they were subject to the criticism previously mentioned, viz., that the heavier mineral remained in the mill longer than was necessary and was consequently ground too fine. It was to obviate this condition and to produce what might be called an unclassified or non-selective product, that brought about the next important development in ball-milling, viz., discharge at a lower level than that of the feed.

One of the recent mills of this type is known as the Marcy, manufactured by the Mine & Smelter Supply Co., Denver, Colo. As shown in Fig. 2 it consists of a cylinder of greater diameter than length, say 8 ft. by 6 ft. The interior is divided into two compartments by an annular grating of manganese steel, which is well illustrated in Fig. 3. This view also shows the nature of the ribbed lining of the grinding compartment, composed of sectors bolted in place. In the discharge compartment, that is between the grating and the discharge end of the tube, there is a series of pockets formed by radial lifters corresponding to the sectors of the grating, much the same as in the Ferraris mill. The grating has linear openings $\frac{1}{8}$ in. wide or less, increasing in width toward the discharge compartment.

The feed end of the mill is fitted with scoop feeders which deliver the ore to the grinding compartment. When the ore is crushed fine enough to pass the grating it flows into the discharge compartment where it is lifted by the radial bars and discharged through the trunnion. In this respect the Marcy mill differs radically from the Ferraris, for the entire pulp is removed from the mill for screening or classification, and the oversize is returned with original feed. Due to the ease with which ground particles pass through the grating, and the rapidity with which they are removed by the lifters, the level of discharge from the grinding compartment is much lower than that of the feed, and as a consequence mineral and quartz particles are removed from the grinding zone with equal facility, and almost as soon as they are ground. This obviates the unnecessarily fine grinding which occurs in a mill with trunnion discharge on about the same level as the feed, wherein the particles have to rise to a high level in order to flow out.

Mills of this type are now being constructed that will take feed as coarse as 4 in. in diameter and deliver a product of 40 or 50 mesh. This makes it possible to eliminate some of the machines heretofore considered necessary in stage crushing in order to reduce ore fine enough for concentration. The best efficiency has been obtained with about 40 per cent moisture in the pulp. The 8 ft. diameter by 6 ft. long mill has a capacity of 1000 tons per twenty-four hours, grinding to 10-mesh; 750 tons to 20-mesh; 350 to 400 tons to 60-mesh. These capacities have been shown on Arizona copper ores. The

power requirement is from 200 to 225 hp., and the ball load from 9 to 10 tons. The balls range in size from 5 in. diameter, weighing 20 lb., to $2\frac{1}{2}$ in. in diameter. The Inspiration Consolidated Copper Co. has installed forty of these mills at Miami, Ariz., each having a capacity of from 350 to 400 tons per day, taking crusher feed as coarse as $2\frac{1}{2}$ to 3 in. and delivering a product that will pass a 48-mesh screen. These mills are in closed circuit with classifiers which deliver the oversize back to the feed end. The cost of crushing, including power, oil, maintenance, etc., is stated to be less than 15 cents per ton, and it is hoped eventually to reduce this to 10 cents per ton. Metal consumption of balls on copper ore amounts to about 0.6 to 1 lb. per ton, while the lining consumption is about one-tenth of this amount.

The simplicity of the modern ball-mill, compared with the Huntington, Chilean and other grinding machines, seems to warrant the belief that it is destined to replace many other forms of mills. It is practically fool-proof and the horsepower required is less than for the machines mentioned, considering mesh-tons crushed. The ball-mill is rapidly coming into use for concentration, cyanidation, flotation and amalgamation, in fact, for all processes in which wet crushing and grinding are used, excepting, of course, where coarse concentration by jigging is desirable.

The Present Situation in Graphite Crucibles

The crucible manufacturers have been put to sore straits for the past eighteen months in the securing of their raw materials.

First came the embargo on Ceylon plumbago. This was lifted after a few months, but the market was left in a depleted condition. The natural result was a tremendous advance in price.

Next came the exhaustion of the foreign clay which is used in crucible making as a binder. As far back as crucible history in this country goes the clay used has come from the little Principality of Klingenberg in the Black Forest of Southern Germany, where, so the story goes, the entire government expenses are paid out of the export duties collected from the clays shipped out. This Klingenberg clay has for years past been the only clay which the crucible makers seemed to think could be satisfactorily used. No shipments of this clay have been made since the beginning of 1915.

Some makers have husbanded the enormous supplies of the foreign clay which they had on hand when hostilities started. This husbanding the stock of the now almost priceless raw material has been done by partially substituting clays from various parts of the United States and mixing them with the Klingenberg clay.

The tests and trials made by the crucible makers during the past twelve months have been almost endless. When it is taken into consideration that it takes from six to ten weeks to prepare a graphite crucible for service in the foundry, some idea can be formed of what the crucible maker has to contend with. Added to this delay and before he can even start on these goods that will not be marketable for two months to come, the chemical laboratory tests and trials must be made. These have run into the thousands. Then must come the practical tests in a small way in the foundry; for the crucible maker would stare bankruptcy in the face if he continued making up hundreds of thousands of dollars worth of goods out of Ceylon plumbago, costing from $17\frac{1}{2}$ to 25 cents per pound, only to find at the end of two or three months that they might not be of service to the user.

The bright side, however, to all that is that in many cases the crucibles made with American clays have stood a surprisingly long time in the fires. In one case there is a report on a No. 300, which ran forty heats on manganese bronze, and dozens of cases as high as thirty-eight and forty heats on No. 100's melting car box metal. The chief trouble now seems to be some lack in uniformity of the products secured. Crucibles made by the same potter out of similar materials, at the same time, and burnt in the same kiln, when run by one melter on the same grade of metals are liable to behave so differently from each other that it is a shock to both user and maker.

All this will in time be rectified. As soon as the manufacturers have become more familiar with the mixing and blending of our native clays, they will no doubt be able to produce in time a crucible as satisfactory as or superior to those manufactured heretofore from foreign materials. The user, however, must use more care in handling the American clay crucibles.

It is imperative that these crucibles are thoroughly dry and warm before going into the fire, and that they are heated up *very slowly* on the initial heat.

Some users make a little fire with charcoal inside the crucible, and others put hot ashes in, before placing the pot in the fire, so that the crucible is hot when it goes into the fire for the first heat. There are certain advantages in heating the crucible first from the inside rather than the outside.

Great care must be taken in the matter of wedging, as American clays have not the same tensile strength when hot, as foreign clay.

The advance in prices of crucibles is due to the unusually high price of Ceylon plumbago just at present, but as soon as the war insurances are a thing of the past plumbago will be at a normal figure once more, and crucibles will again be marketed at as low prices or lower ones than they have been for many years past.

A New Electrolytic Oxygen and Hydrogen Installation in a Shipbuilding Plant

At the present time most large users of oxygen for commercial purposes are purchasing it from the manufacturers, having it shipped to them in cylinders containing 200 cubic feet at 1800 lb. pressure. As this entails freight expenses and handling at point of consumption, various large users of oxygen for welding and cutting purposes have installed or are installing their own generating apparatus at their plants.

A new electrolytic oxygen and hydrogen plant just finished and put into operation by the National Ox-Hydric Co. of Chicago at the works of the Fore River Shipbuilding Corporation, Quincy, Mass., is complete in every detail, self-contained, and is run entirely automatically, requiring only the attention of one man to a shift, the plant being run continuously by three men in three eight-hour shifts.

The plant consists of a 75-horsepower Bessemer crude-oil engine, belt-connected to a 45-kilowatt direct-current generator; one of the National Ox-Hydric Co.'s electrolyzers, as shown in the adjoining illustration, guarantees to produce 3500 cubic feet of oxygen per 24 hours and twice that amount of hydrogen; suitable gasometers, compressors, motors and switchboards for control.

The oxygen and hydrogen, after being produced from the electrolyzer, passes into steel gasometers of 2000 cubic feet capacity each. From there they pass through a suction line into suitable compressors, which boost the pressure in the pipe lines between the gasometers and point of consumption to the amount

required at the blowpipes. Between compressors and blowpipes or operating stations, are suitable concussion tanks to take the pulsation of the compressors off the pipe lines.

The plant at the works of the Fore River Shipbuilding Corporation is also equipped with high-pressure compressors for the purpose of compressing oxygen and hydrogen into cylinders where it is not advantageous to run pipe lines, such as on board ships and other extreme points of the company's shipbuilding yards. The erection of this plant was begun on December 15, 1915, and entirely completed by February 1, 1916. It is installed in a building of pressed sheet steel 24 x 40 feet.

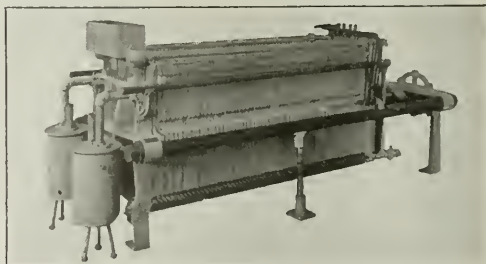
The National electrolyzer is of the improved filter-press type. The present perfected machine is the result of years of study and experiment on the part of expert gas engineers, whose experience and knowledge are based upon extended and exhaustive research and whose work has made it possible for the company to produce a simple and inexpensive method for the production of oxygen and hydrogen gases at a low initial cost.

Fundamentally, the National filter-press type of electrolyzer consists mainly of a number of decomposition chambers connected in series. These chambers are formed by clamping together a series of cast-iron electrodes so recessed and grooved that each plate forms, with its neighbor, a chamber which holds the electrolyte, and in which the generation of the gases takes place.

The electrodes are carefully insulated one from the other by means of patented rubber-bound asbestos diaphragms. The electrodes and diaphragms are arranged alternately and are supported by the insulated frame of the filter press. The required number of electrodes and diaphragms with the corresponding end plates are then pressed tightly together by means of a heavy screw standard, thus making the whole equipment form a hermetically sealed tank of the filter-press type, the diaphragms serving both as an insulation and gasket, and serve to form the sides of the cells, preventing any mixture of the two gases generated. The fact that the electrodes are thus separated by the diaphragms causes one side of the plate to act as the anode of the chamber and the other side as the cathode of the adjacent chamber.

The electrodes are composed of a special alloy, and are heavily coated with nickel, which makes them neutral to oxygen and alkali (from the potash) and prevents the formation of deposits or the oxidation of the electrodes themselves.

The number of chambers required is, of course, dependent upon the production of gases required, as well as the voltage of the electric current. The elec-



FILTER PRESS ELECTROLYZER FOR THE PRODUCTION OF OXYGEN AND HYDROGEN

trolyzers of the National Ox-Hydric Co. are designed for any standard direct current circuit, or, with the use of a motor-generator set, for any of the standard alternating current circuits, thus doing away with the inefficient low voltage, high amperage necessary with the individual-cell type installation. Furthermore, these electrolyzers occupy about one-fifth the floor space, and in many instances less than one-fifth of the floor space, required by the individual cell type.

By the design of electrode the anode and cathode are brought close together, so as to reduce to a minimum the electric resistance, while at the same time the hydrogen gas is effectually kept separate from the oxygen gas without preventing the proper passage of the electrolytic solution between the anode and the cathode.

The electrodes themselves are made with corrugated surfaces, increasing the active electrode surface and forming a large number of very small vertical channels through which the gases rise freely to the upper part of the plates. At the top of each electrode and hermetically sealed together are substantial chambers in which the gases are separated from the electrolyte. From these chambers the gases pass off in a dry state into ducts extending through each plate, these ducts forming continuous conduits, owing to the manner in which the plates are assembled. The gases pass through these conduits into their respective receivers or storage tanks. One of the main features of the design is the way in which the conduits are kept free from electrolyte; this is accomplished by one of the most practical devices known to the gas industry, which device is cast integral with each plate, thereby eliminating any possibility of a short circuit even should the conduits become filled with the solution.

The electrolyte is a 21 per cent solution of pure caustic potash in distilled water. After the electrolyzers are once filled with this solution, distilled water is added from time to time to take the place of the water decomposed; the potash lasts many months. The distilled water is fed to the electrolyzer by an automatic device which maintains a constant level of the electrolyte throughout the machine.

Under normal load conditions, the voltage required per cell is two volts or less. Therefore, to operate on a 110-volt circuit an electrolyzer containing 55 cells is necessary; and on the same basis, 110 cells are necessary for a 220-volt circuit.

The positive pole of the direct-current dynamo is connected with the first electrode in the series, and the negative pole is connected to the last electrode of the series.

The apparatus is provided with one collector for hydrogen and one for oxygen, whereas, the individual-cell type system must have a separate draw-off, or collector, for each cell in use, which necessitates more labor and a considerable increase in upkeep.

Insulation difficulties have been eliminated which prohibit short-circuits and groundings and make the cost of maintenance very small, the labor operating cost being practically negligible.

Assuming continuous operation and normal load conditions as specified by the company, the electrolyzers yield 4 cu. ft. of oxygen and 8 cu. ft. of hydrogen at atmospheric pressure per kilowatt hour of power consumed when the plant is operated at a temperature of 68 degrees F.

The gases produced are of very high purity. The oxygen is of 99.5 per cent purity. The electrolyzer will stand an overload of 50 per cent without any ill effects. This feature of being able to considerably

overload the plant and generating a proportionally greater amount of gas is of great advantage.

The operator of one of these electrolyzers should in all cases make a chemical analysis at regular periods of the oxygen and hydrogen gases produced, testing their purity. Other than that his only duty is to maintain a proper water column level of the electrolytic solution.

The water of which the electrolyte is formed has to be distilled in the large commercial plants by means of a properly installed still, but in the smaller individual plants the purchase of distilled water in quantities sufficient to successfully operate the plant is advocated.

The electrodes are practically indestructible. The asbestos diaphragms are very durable, and being neutral to the elements with which they come in contact, have a life fully equal to that of the electrodes. All other parts of the equipment are practically not subject to any wear and tear.

Industrial Notes

The Benzol Products Company, Marcus Hook, Pa., will erect a research laboratory and make other additions to its plant representing an expenditure of \$45,000.

The American Coal Products Company, it is officially announced, has decided to unite its name with that of the Barrett Manufacturing Company and the new name will be the Barrett Company. The new company will have the same amount of stock as the American Coal Products Co., which concern was the parent organization of the Barrett Manufacturing Co. and owned its stock.

The International Acheson Graphite Company of Niagara Falls, N. Y., has changed its name, and hereafter will be known as Acheson Graphite Company. It will be noted that the word "International" has been dropped and that the company name now begins with the name of the noted inventor of the process for making graphite artificially in the electric furnace. The change was brought about through the conception that the word "International" had no significance in the company's business and only served to conceal the identity of the company when indexes and other references were examined for the name and address.

The Stupakoff Laboratories, Pittsburgh, Pa., are erecting new laboratories on Hamilton Avenue, and during the erection they are temporarily located at 6364 Frankstown Avenue.

New Lining for Combustion Boats.—The Scientific Materials Company, Pittsburgh, Pa., has placed on the market a new material known as sinderite for lining combustion boats for direct combustion of carbon in steel analysis. The material was developed by the company's research department and is stated to be free from carbon and not to absorb CO_2 from the atmosphere, while possessing other valuable properties which make it a protection to platinum and the combustion tubes.

The Bausch and Lomb Optical Co. has issued a catalog describing its optical instruments for inspection and testing of materials. This includes microscopes and photomicrographic outfits for the examination of ores, metals, rocks, concrete, wood, leather, fabrics, paints, varnishes, oils, dyes, inks, drugs, chemicals, and foodstuffs.

The Chain Belt Company, Milwaukee, Wis., has issued a supplement to their general catalog No. 56. The supplement contains revisions of the general catalog both pertaining to prices and dimensions.

Annealing Cast Bronze.—A study has been completed by the Bureau of Standards, of the annealing of bronze; zinc bronze (copper 88, tin 10, zinc 2) as a type and the results published in Technologic Paper No. 80 which may be obtained without charge from the Bureau of Standards, Washington, D. C. The title of the publication is "Microstructural Changes Accompanying the Annealing of Cast Bronze."

Safety-First Exposition.—A safety-first exposition by government bureaus was held at the New National Museum in Washington, Feb. 21 to 26. Twenty-six bureaus participated in the exposition and apparatus in use by the federal government was demonstrated by experts.

Experiments in Use of Niter Cake.—In the search for a substitute for sulphuric acid, several mills in Yorkshire, England, have carried out experiments in use of niter cake, according to Commerce Reports. The experiments were made in connection with the extraction of grease from suds, for the refining of grease, and other purposes. The chief difficulties are those of handling, drawing of the acid liquid in storage and handling, and difficulty in transportation. The best method is said to be to dissolve the cake in hot water by the aid of steam and to use this solution hot.

Chemical Engineering at University of Michigan.—A special bulletin has been issued by the University of Michigan describing the chemical engineering course and graduate fellowships in gas engineering metallurgy, paint and varnish manufacture, and pulp and paper manufacture. The chemical engineering department, since its foundation in 1898, has been an integral part of the College of Engineering.

Pittsburgh Section American Electrochemical Society.—The regular meeting of this section was held on Jan. 14, Prof. S. L. Goodale spoke on "Some Observations on the Heat Treatment of Steel," illustrated by a projecting microscope using actual etched samples. C. G. Schluederberg was elected chairman and H. C. Ray, secretary-treasurer for the coming year.

The Montana Section of the American Institute of Mining Engineers held its annual meeting and banquet on Feb. 14, at the Silver Bow Club, Butte, Mont. The following officers were elected: Chairman, J. L. Bruce; vice-chairman, W. C. Siderfin; secretary-treasurer, M. H. Gidel; executive committee: N. W. Braly and W. T. Burns. The speakers were Prof. D. C. Bard, who talked on oil prospecting, and Frederick Laist, who talked on zinc metallurgy as practised at Anaconda.

Cornell's Chemical Department Burned.—Morse Hall, seat of the chemistry department of Cornell University at Ithaca, N. Y., was destroyed by fire on Feb. 13. Much valuable apparatus and chemicals were consumed and the loss is estimated at \$300,000. The main building was erected in 1890 and it was twice enlarged, Andrew Carnegie giving \$60,000 for a recent addition. Several hundred students saved books from the library on the first floor, and the records of the department. Insurance to the value of \$200,000 was carried.

Rope-Operated Controllers for Small Cranes and Hoists.—A new reversible drum-type controller designed for overhead mounting, with rope operation is being introduced by the Cutler-Hammer Mfg. Co., Milwaukee, Wis. These controllers are designed for installation indoors for intermittent speed regulating duty, such as in crane and hoist service. Two types are made, one giving 50 per cent speed reduction under half full load current and the other 90 per cent under light load conditions.

Compound for Removing Scale.—A substitute for sulphuric acid for removing scale from iron, steel, brass, copper, etc., which is finding increasing use at present

on account of the high cost of acid is manufactured by the Research Mfg. Co., Oak Lane Station, Philadelphia, Pa. Special progress is being made in the following trades: rods, flats and tubes to be cold drawn; sheets to be tinned or galvanized, brass and copper shells, some grades of castings and forgings. It is adapted for the removal of scale from any metal whether for pickle finish, cold drawing, tinning, galvanizing or enameling. The compound, which is known as Edis compound, is shipped in dry cakes and can be handled readily. It is dissolved in water and heated to 180 deg. Fahr. for use. The vapor is claimed to be non-irritant and not injurious to health.

Personal

Dr. John A. Brashear, past president of the American Society of Mechanical Engineers, will be the guest of honor at a banquet given by the Engineers' Society of Milwaukee, Wis., on March 21.

Mr. W. T. Burns has been promoted to the position of superintendent of electrolytic refineries for the Anaconda Copper Mining Co. at Great Falls, Mont., and will have charge of both the copper and zinc electrolytic plants. Mr. E. E. Brownson, formerly chief chemist, has been promoted to be assistant superintendent of the electrolytic copper refinery.

Mr. Herman A. Holz, who has been connected with the Scientific Materials Co. of Pittsburgh for the past five years, has opened offices and showroom in the Hudson Terminal Building, 50 Church Street, New York City. Mr. Holz will deal in precision instruments of high quality for industrial, scientific and military purposes, and will make a specialty of metallurgical research and testing apparatus, pyrometers and hydrostatic recording instruments for pressure, vacuum, volume and velocity of air and gas currents in industrial plants.

Mr. Woolsey McA. Johnson is making a professional trip to Kansas and Oklahoma and expects to return in about two months.

Mr. John G. Kirchen, general manager for the Tonopah Extension Mining Co., has been elected president of the Nevada Mine Operators' Association.

Mr. David H. Ladd of Houghton, Mich., formerly metallurgist of the Wallaroo smelter, Australia, has been appointed general manager of the Sandusky Foundry, Sandusky, Ohio.

Messrs. Dorsey A. Lyon and O. C. Ralston of the Salt Lake office of the U. S. Bureau of Mines, are making a field trip through the central West investigating the general subject of flotation. They held a conference with other metallurgists at Lawrence, Kan., with a view to arranging co-operative work on flotation experiments and research.

Mr. Wm. H. Nichols, Jr., has been elected president of the General Chemical Company, succeeding Sanford H. Steele, who retired to become general counsel of the company.

Mr. H. O. Swoboda has been engaged as consulting engineer by the Humphrey Company of Kalamazoo, Mich., to design a line of electric water heaters.

Messrs. Theodore S. Tenney and Arthur K. Ohmes will continue in business as consulting engineers for heating, ventilating and power plant work at 101 Park Ave., New York, under the name of Tenney and Ohmes. Mr. Werner Nygren has withdrawn from the company and will practice independently at the same address.

Dr. Ludwig A. Thiele announces his establishment as an independent consulting chemical engineer with special knowledge of the design and construction of acid and fertilizer plants. His office will be in the Hartman Building, Columbus, Ohio.

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The Place Value of Waterpowers

In this issue we publish an interesting letter by "A. C." who asks whether we are not becoming unduly excited over Niagara power, and suggests the possibilities of cheap power from gas and the prospects of developing other waterpowers outside of Niagara. His are sensible questions. There is no doubt that in the directions indicated by him an enormous amount of hard and progressive work remains to be done. Think alone of the existing beehive coke ovens and what could be done with by-product coke ovens. Other waterpowers than Niagara in other parts of the country also have a serious right to be taken into consideration. As a single example, Muscle Shoals on the Tennessee River, if developed, might offer an excellent location for a cyanamid factory—with the Southern fertilizer market at its doors and protected by its inland location against foreign aggression if the factory should be turned over to making nitric acid for explosives in case of war. But this example also brings out clearly one point which is usually overlooked, that is the "place value" of a waterpower. As things are, most of the potential sources of cheap power which remain to be developed, will be linked to certain specific industries by considerations of raw materials supply and market.

Dr. Baekeland some ten years ago said that one chief factor determining whether a chemical process would work successfully, was Mr. Edward Harriman. Mr. Harriman is dead, but Dr. Baekeland's remark is as true to-day as it was ten years ago. That transportation costs play an enormously bigger part in the industrial life of this country than that of any other country, can be shown by a few indisputable comparative figures. As a basis we will use a few figures given by Mr. J. R. Finlay in his admirable paper on "industrial energy as a military weapon," published in our issue of Sept. 1, 1915 (Vol. XIII, p. 547). Mr. W. L. Saunders, in his speech last month before the New York section of the American Electrochemical Society (our issue of March 1, 1916, p. 259), based his convincing argument on a similar line of thought. Mr. Finlay considers as one chief criterion of a nation's industrial activity the consumption of fuel. This is 5 tons per capita for the United States, 4 tons per capita for England and Germany, 1.6 tons per capita for France, 0.25 ton per capita for Russia. These figures are a direct indication of the degree to which a nation has succeeded in multiplying the natural working productiveness of its average citizen by industrial development. Clearly the United States is easily the foremost industrial nation; the industrial output per man is greater in the United States than in any other country. Now let us change the viewpoint and instead of considering tons of fuel per capita

let us consider tons of fuel per square mile of area of the country. We leave it to our readers to calculate the figures. Without figuring at all, it is at once evident that the sequence of the figures for the different countries is entirely upset. What does this mean? Nothing more than that this country is very much less industrially populated than England or Germany and that the cost of transportation between the different industrial centers among each other and between industrial centers and sources of raw materials and markets respectively must be very much greater. In parenthesis it may be said that just this consideration explains why in the chemical industries certain things are possible in Germany which are impossible in this country.

If the economic value of a commodity is made up of place value, time value, and form value, and if place value is determined by transportation costs, it is thus clear that the place value is much more important in this country than abroad. This is necessarily true also for waterpowers. What has given Niagara its unique position among American waterpowers is its connection to the great lakes, with 3600 miles of shore line and navigable to the very docks at Niagara. The least expensive sort of transportation is thus provided for Niagara products to markets representing nearly half the population of North America, while the least expensive supply of raw materials is provided in many cases by the same water way, quite aside from the railroads running from Niagara in all directions.

This journal pledges its full support to any sensible waterpower development in any part of the country. But as things are at present, we must insist that, as a matter of fact, among American waterpowers Niagara Falls is in a class by itself. It is the place value of Niagara Falls which in conjunction with the available power makes it a national asset of unique economic value to the American nation. If the waste of power at Niagara is continued in future as heretofore, the only real loser is the whole American nation.

Value of Continuous Operation in Ore-Testing

Engineers experimenting with the flotation process are having their attention drawn to the value of continuous operation on a small scale in order to secure the most reliable data. It has been customary when making preliminary tests by the agitation-froth method, for example, to use a small single-cell machine and a few ounces of ore, keeping the pulp in closed circuit until no more froth is obtained. From such tests we get an approximate idea of the efficiency of oils, grade of products and general applicability of the process.

On the other hand there are certain factors which are not determined by such tests on a single-charge system. In practical application of the process various flow-sheets may be employed: A rough concentrate from several cells may be cleaned in another set; a middling product may be returned continuously and combined with the original feed; oily water may be recovered from concentrate or tailing, or both, for re-use; in short, commercial practice varies from the conditions of small

tests by introducing factors that may have a cumulative effect not observable in an experiment with a single charge. The latter will not reveal the effect on the grade of concentrate caused by continuous return of middling, nor will it show the influence on oil consumption produced by use of recovered water. Therefore continuous testing on a small scale is advocated in order to observe the cumulative effect of certain factors and permit correct deductions.

To a certain extent the same principle applies to other metallurgical work. In cyaniding, for example, continuous operation shows the chemical effect of certain inconspicuous elements or compounds in the ore which may exert their full influence only after they have accumulated in solution. The same is true of smelting, where the recovery and retreatment of by-products acts as a concentration process for deleterious substances that are not in evidence in the beginning of operations. Copper and zinc leaching and electrolytic deposition are other examples of processes in which complete information cannot be obtained by intermittent or charge tests. It has long been recognized that so-called "full scale" tests are not essential for preliminary investigations, but the principle of continuity on a small scale seems to be sound in cases where it is at all practicable. Where it is not, refined chemical analysis of the ore will be of marked assistance in forecasting the necessary precautions and the probable results.

Need of Ball-Milling Data

The ball-mill is making a strong bid for popularity as a crushing machine, and some of its advocates enthusiastically see the beginning of the end of stamps, Chilean mills, Huntington mills and other competing types of crushing and grinding apparatus. Considering the comparatively recent advent of the modern type of ball-mill, its performance excites interest and admiration and lends color to the claims of its optimistic supporters. There is no doubt that the machine will grind ore in large quantities and effect a satisfactory reduction in size at one passage through the mill. Due to the rapidity with which the crushed ore is removed from the crushing zone and discharged from the mill, the product is granular and well adapted to gravity concentration or flotation.

Aside from figures on tonnage, screen analysis and power, however, data are meager; and such as are available have only local significance. Installations are comparatively new as well as few, and mills have not been in operation long enough to afford reliable data on cost and efficiency in comparison with other types of grinders. It would be instructive, for example, to compare in every essential detail the work of the modern ball-mill with that of the Chilean mill in the Cripple Creek district where the latter has shown a remarkable performance.

Time and experience will verify the correctness or falsity of the figures on mesh-tons crushed per unit of power and the cost for repairs on ball-mills, and afford some basis for comparison with other machines. Meanwhile there is an absence of data and exact knowledge

on the most economical load of balls and size of balls for a given size of mill, as well as the correct ratio of the different sizes of balls in the total load. Determination of these factors would indicate the correct procedure in adding new balls to the load, not only as to quantity but also as to ratio of sizes.

It would seem, for example, that there is a correct ratio of sizes that will fill the grinding zone to the best advantage, giving the proper percentage of voids and the proper number of points of contact for efficient grinding. Assuming a mill to have been started with ball sizes in correct ratio, it would seem to follow that future additions of balls should be of such sizes and quantities as to maintain the original ratio. In practice, however, it is not uncommon to replenish the supply by adding only the largest balls, on the assumption that they will be reduced in size and keep the ratio constant.

Is this assumption correct? If we fill a cylinder with balls of, say, three different sizes, it will be found that the number of each size that can be introduced increases with startling rapidity as the size decreases. Assuming this condition to represent the desired ratio of sizes for efficient grinding, it becomes apparent that the largest balls, which are least in number, cannot be depended upon to furnish the requisite supply of small balls which originally existed in much greater number. If this is true, then small as well as large balls should be supplied to keep the crushing load constant in weight and in ratio of ball sizes.

The whole subject of ball load is worth investigation for the purpose of securing definite data on the most efficient manner of operating ball-mills. The matter could well be investigated in the testing laboratories of our schools of mines, or by large operators, or even by the manufacturers.

The Pig Iron Production Statistics

Pig iron production in the United States in 1915 is officially reported at 29,916,213 gross tons, according well with the estimate of 29,900,000 tons made in our review at the beginning of this year. The year's output fell 3.4 per cent short of the output in the banner year 1913, 30,966,152 tons, but the output in the second half of 1915, 17,682,422 tons, broke the record for a half year, 16,488,602 tons, in the first half of 1913, by 7.3 per cent. The present indications are that 1916 will show an output close to if not quite 40,000,000 tons, which would break the calendar year record by 29 per cent.

The sharpness of the swing from Bessemer to basic open-hearth steel is shown by the fact that while the output of basic pig iron in 1915, 13,093,214 tons, broke the previous record, made in 1913, by 4.4 per cent, the Bessemer output, 10,523,306 tons, fell short of the production in seven of the preceding years, and was but a negligible amount in excess of the output in 1902. The present year will show as large an output of Bessemer iron as the existing Bessemer-steel-making equipment can consume, but as some of the equipment has passed to the scrap heap and some has been diverted to the

duplex process it is a question whether the output will equal that in the banner year 1906, 13,840,518 tons.

The large steel works and even the moderate sized works, are practically self-contained as to pig iron. The tonnages made for sale, chiefly by regular merchant furnaces, as only a few steel interests, exceptionally placed, sell any pig iron, was as follows in 1915, with the proportion the merchant iron constituted of the total output:

	Gross Tons	Per Cent
Basic	1,747,265	13.3
Bessemer and low-phosphorus	871,730	3.3
Foundry	4,801,711	95.7
Malleable	829,921	100.0
Forge	174,355	52.2
All other	158,025	54.6
Total	8,583,007	28.7

The tonnage designated above as "all other" included spiegeleisen, ferromanganese, direct castings, etc. While the merchant production was 54.6 per cent of the total there is little doubt that more than one-half the spiegeleisen and ferromanganese was made by steel interests.

The production of ferromanganese in the year was 129,072 tons, breaking the previous record of 125,378 tons, made in 1912, by a small margin, but the production in the second half alone, 83,628 tons, was undoubtedly far in excess of the tonnage made in any preceding half year, and represented fully 70 per cent of the maximum requirements hitherto experienced, in 1912 and 1913. While the production of steel is much larger, the means employed at many works for getting along with smaller proportions of ferromanganese are probably sufficient to reduce materially the total consumption of ferromanganese in proportion to the steel output. The use of spiegeleisen and ferrosilicon, for instance, has been greatly increased.

The statistics of the tonnage of iron delivered molten shows that there is very large employment of the direct metal process. Of the total output of Bessemer and low-phosphorus pig iron the tonnage delivered molten was 70.7 per cent. Making allowance for a relatively small tonnage of Bessemer that is delivered molten by merchant furnaces to ingot mold foundries, and deducting an estimate for the low-phosphorus output, it would appear that the steel interests used about 78 per cent of their Bessemer pig iron output as direct metal. The remaining 22 per cent of iron that was cast was not all "Sunday metal" by any means, as commercial conditions were such in the early months of the year that a considerable tonnage was doubtless cast for stock, to be carried weeks or months. A year like the present will probably show a much higher proportion than 78 per cent.

Of the total production of basic iron in 1915 73.8 per cent was delivered molten, the highest proportion yet shown. Substantially all the merchant basic iron was undoubtedly cast, so that the 9,648,769 tons delivered molten may be compared with the 11,345,949 tons produced by steel interests, showing a proportion of 85 per cent direct metal, and leaving room for the introduction of very little additional refinement in making the blast furnace and open-hearth furnace work hand in hand.

Reader's Views and Comments

Power from Niagara Falls and from Other Sources

To the Editor of Metallurgical & Chemical Engineering

SIR:—Are we not becoming unduly excited over Niagara power? Can we not have a discussion on the cost of power from various sources?

For example, natural gas sells for 5 cents per 1000 cu. ft., or less, in some sections of the West Virginia field. With the most efficient type of gas engine it would seem as though power from this source might work out as cheap as Niagara power. And salt is at hand.

And with the Mond producer-gas process gas seems almost a by-product—without cost—of a chemical plant producing a very high yield of ammonia, together with the usual tar products, and coke. Locate such a plant on a culm bank at the mine, convenient to salt, and low costs should result.

And then what is the matter with other water powers? Is not the Mississippi Power Co. at Keokuk, Iowa, looking for business? What about Massena, N. Y.? There are doubtless many locations in our own state (the upper Hudson, for example) and in New England where developed and undeveloped large and small powers are available.

Finally, it ought to be possible to buy current of some of the great central-station companies in our larger cities. Prices approximating $\frac{1}{2}$ cent per kw-hour—for certain uses—have been rumored. Of course, any such rate would only apply to those hours of the day when the regular lighting and power load is unusually light. Here regular service takes care of "overhead charges," so that anything in excess of coal costs, plus additional labor, wear and tear and supplies, should be profitable.

What does Niagara power cost the consumer?

A. C.

Brooklyn, N. Y.

Congress and the Dyestuff Situation

To the Editor of Metallurgical & Chemical Engineering

SIR:—The Right Honorable, the LXIV Congress is now in session. It assembled on Dec. 6, 1915, and adjourned for the holidays on Dec. 17. During that period 6848 bills were introduced of which 4144 (which sounds almost like four-leven-forty-four) were pension bills of which practically every one had been already presented to the pension office and rejected. One honorable member is the happy father of 208 of these bills. There were also introduced 198 bills changing military records, which are increases in pensions, and 1037 bills for claims which the United States Court of Claims had not regarded as sufficiently justified to approve. There were 718 local bills in which the people of the United States had no interest whatever as, for instance, one (H. R. 409) "authorizing the Secretary of War to donate to the City of Elsberry in the County of Lincoln, Mo., two bronze cannon or field pieces, with their carriages." It requires the deliberations of the 434 members of Congress at \$7,500 per year plus mileage to determine the future of Elsberry's hitching post! Of the 758 additional measures proposed and called for politeness' sake public bills, over one-half of them were, in point of fact, of private rather than public interest. I have these details from the bulletin of the National Voters' League.

Now the only possible good to come from these enact-

ments is Votes for Congressmen. The Pension Department and the Court of Claims are discredited and their work made of no avail; the lavish waste of money is like nothing more sober than a drunken sailor, and if it were not for the inestimable boon of having the present incumbents remain in the place of others who might be elected to succeed them in Congress after the next election, it would almost seem as though the money were spent for nothing.

These things give us something of a jolt. And yet, these gentlemen are the real representatives of the people; they are the means whereby democracy is justified—or fails. Congress is *us*, and if we do not like it let us at all events quit boasting and stop complaining. Neither will do any good. It all comes back to abuse of ourselves, for these are our representatives and we have elected them. Our Congressmen are our contribution to Democracy. The Civil Service men have nothing to do with what the gifted orator calls the In-stye-tootun o' Liberty; neither have department chiefs nor cabinet ministers. Congress is the people; and there's many a conscientious, able and earnest man in that body.

Then what's the matter with it?

Despite all that I have said there isn't anything in particular the matter with Congress. The matter is with us, us citizens. We haven't kept watch; haven't paid attention to what Congress did. It has not been interesting and so we have let the whole thing go by the board and we have satisfied our consciences by kicking at the politicians. Of course, some manufacturers have taken an interest in Congress, a very selfish interest that hasn't done Congress any good, but we do not refer to the lobby when we refer to patriotic interest. We have just let things slip along until bad practices have crept in. Then they have become general; like the bribery of dyers. We do not pay any attention to Congress until something important like war or a question of honor, or a general welfare or a tariff bill comes around; and then we expect Congress to act. Now Congress with the best intentions does not know what we want—unless we are manufacturers, and then Congress is likely to learn that we want more protection than a mud-turtle-porcupine hybrid. Otherwise we do not tell Congress anything. Congress knows (by experience, probably), that if we had a civil war record we should probably have put in appearance already, and if we do not want a position or some privilege or advantage, then we have no business with Congress. And Mr. Congressman addresses himself to the only people who seem to have business with Congress, to wit: those who want money and those who want favors. No wonder there are so many special bills; those are the very bills that count—to the Congressman. "Take all this yawp and hullabaloo about the dyestuff situation," he is likely to say. "People are making just the same kind of a noise that they always do whenever there is a tariff discussion." Mr. Congressman has heard that noise before and he wants to know why it means any more than it usually does? And if there isn't a single textile mill of any importance in his district, which is usually the case, what's the use, Mr. Congressman wants to know, of making such a fuss about it? Where does he come in? You see, half the Congressmen, irrespective of party, are built this way and think this way. Experience in public life has taught them what the public wants, which is pensions and favors. Then, if a man keeps regular with his party and looks after the boys in

his district pretty well, his political future is fairly well assured—until the next landslide. So it is a pretty good plan to introduce bills for everything that can help a man, politically, in his district and then use them for trading purposes later.

What is the refrain that we constantly hear before elections at political meetings—provided we go and listen? Almost invariably it is "Vote for Hon. John R. Gobblevote for Congress. He looks after the people of This District." There are the two bronze cannon and their carriages, put there by special Ack o' Congress, and the village drunkard with his pension and the dashing young widow with hers and appropriations for this and that and t'other. That's what counts!

So if a chemical schedule goes through, even though it be approved by the wisest and soundest and best informed of commissions and committees, we may be sure that it will carry with it a million or so a year in pension bills that have heretofore been rejected.

Bills for disallowed claims and rejected pensions are the yellow trading stamps of The People. By them our rights are conserved and good government is purchased.

X. Y.

A Nomographic Blast-Pressure Chart

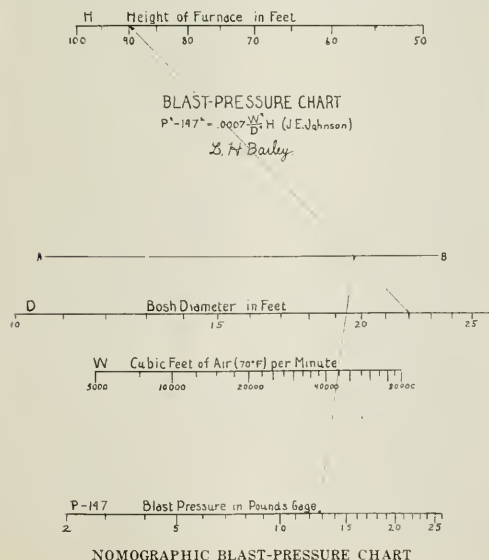
To the Editor of *Metallurgical & Chemical Engineering*

SIR:—In looking over your Jan. 1, 1916 number, I was greatly interested in the remarkable contrast between Mr. Haylett's charts on page 9 and the one on page 44 in connection with Mr. Johnson's excellent article on the blast-furnace. The construction of the accompanying chart is a matter of an hour or a little more and gives the same results as the rectangular chart in about one-third of the "one minute" claimed by Mr. Johnson.

Mr. Johnson's formula,

$$P = 14.7 + .0007 \frac{W^2}{D} H,$$

by the use of nomographic methods, can be represented by four graduated scales for the four variables and one supporting line *AB*. The application of this chart to the solution of problems is extremely simple.



Example: Height, 90 ft., bosh diameter 22 ft., blast 45,000 cubic feet. What pressure is required?

Solution: Connect 90 ft. on the *H* scale with 22 ft. on the *D* scale. From the point of intersection of this line with line *AB* draw a line through 45,000 on the *W* scale. This line will cut the *P* scale in the required value, 13.7 lb. gage.

As will readily be seen it is just as simple to solve for the volume of air, when the gage pressure and furnace dimensions are given.

I think Mr. Johnson will agree that of the two charts, the nomographic chart is much simpler to construct and much less confusing to use.

LAWRENCE H. BAILEY.

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Massachusetts Institute of Technology,
Boston, Mass.

Classifying

To the Editor of *Metallurgical & Chemical Engineering*

SIR:—I have read with interest Mr. E. S. Wiard's valuable article in your issue of Jan. 15, on "The Grading Industries."

The discussion of the type of grading which he states is incorrectly called "classifying" is of necessity limited, in such a comprehensive paper; and I would like to add to it some further data on the work of the machine with which I am identified.

The word "classifier" to describe a device for separating a stream of pulp into only two products came into use in cyanide metallurgy when leaching sand was practised and more attention was paid to sand and slime separation, and when cones with an upward or washing current were adopted instead of the collecting tanks or spitzkasten. When in 1904, after a troublesome experience with the so-called "cone classifiers," the idea of accomplishing the same separation by removing mechanically the sand from a settling vessel occurred to me, it was natural to call the resulting machine a "classifier," especially as I did not realize then that mechanical devices had been frequently used in concentrating mills for sand dewatering. The wide adoption of my own and later developed types of mechanical "classifiers" in cyaniding, and their value in fine grinding in closed circuit for the "all-slime" treatment, brought them to the attention of concentrating men. The scope of their work has been increased from the original separation of leachable sand, (often a large per cent under 200 mesh) and colloids, to making a —200 mesh or —150 mesh so-called "all-slime product," and finally to making a separation at 48 and 60 mesh, such as is being done with our machines at the Inspiration and Anaconda in preparing a flotation product.

Surely such machines should no longer be called "dewaterers" or "deslimers," as many of my concentrating friends have insisted.

We all realize the difficulty of obtaining reliable data on the performance of different types of machines, and know how easy it is to get incorrect impressions due to the incomplete data that get into circulation. The comparative tables given by Mr. Wiard illustrate this very well. He states: "Table 1 illustrates the capacity and work of the three classifiers. The figures in the case of the Dorr and the Akins are comparative, having been made in the same mill on the same material." (The italics are mine.)

As the feed given showed only 76 tons going to the Dorr with an overflow of 19.4 per cent plus 200 mesh and 92.7 tons to the Akins with an overflow of 22 per cent plus 200 mesh (practically the same), the only inference to be drawn would be that the former had less capacity at that point of separation.

On reading his paper I recognized the screen tests

at sight and felt that as they had been published, further information was warranted in the interest of entire accuracy. Nearly five years ago, the same screen tests were brought to me as having come from the superintendent of a well known mill and as being used by others to prove that the Dorr machine had the smaller capacity. Realizing that capacity is largely a matter of settling area, and knowing that the Dorr machines were handling much greater tonnages elsewhere, I called on the superintendent, who assured me that in sending out the tests to inquirers he had not intended to imply that the data represented what he considered the comparative capacity of the machines, but only the feed when the tests happened to be made.

He regretted that any incorrect inferences had been drawn, and very kindly offered to make further tests. These were made under his supervision and the results sent us by him, as shown in Table I.

TABLE I. CLASSIFIER TESTS BY — COMPANY

Received from — July, 1911. Dilution of feed about 4:1.			
Feed Dorr about 145 tons per 24 hours.		Feed Dorr about 145 tons per 24 hours.	
Feed Akins about 145 tons per 24 hours.		Feed Akins about 75 tons per 24 hours.	
Heads	July 12, 1911	Heads	July 6, 1911
	Dorr		Akins
+40	12.8%	+40	9.4%
+60	16.8	+60	20.3
+100	8.3	+100	11.6
+200	13.4	+200	11.6
-200	47.1	-200	47.3
Slimes		Slimes	
+100	0.2%	+100	14.3%
+200	8.7	+200	17.5
-200	91.2	-200	68.0
Sands		Sands	
+40	34.7%	+40	36.4%
+60	29.1	+60	42.1
+100	14.2	+100	9.9
+200	13.5	+200	7.4
-200	7.9	-200	3.3

Daily tests on Dorr loaded at 145 tons per 24 hours

Slimes	1	2	3	4
+100	0.2%	0.7%	1.6%	1.7%
+200	6.4	9.4	5.4	9.7
-200	93.4	89.9	92.9	90.3
Sands				
+40	26.5%	28.0%	25.8%	36.9%
+60	29.1	30.0	30.5	30.6
+100	13.2	17.6	16.4	13.8
+200	18.5	14.8	17.6	12.8
-200	12.0	9.6	8.5	6.1

These figures are much closer to those obtained with Dorr classifiers under similar conditions elsewhere, and taken together certainly can be considered more informative than the single one previously given.

On discussing the matter with Mr. Wiard, he advised me that he had received the figures he had published some years ago, and was glad to have me publish the others as well.

The figures of Table II from other plants may be of interest as showing the capacity of the classifier under varying conditions.

TABLE II. SCREEN TESTS

Standard Duplex Classifier, not in closed circuit. Feed 155 tons per day from stamp battery. Screen test of feed not given.

Mesh	Sands	Overflow
+10	15.0%	...
+20	16.8	...
+60	40.0	...
+100	14.0	0.2%
+150	4.2	1.0
+200	4.6	2.8
-200	4.9	96.0

Standard Duplex Classifier in closed circuit with a tube mill. Original feed to classifier..... 55 tons
Classifier sands or tube mill return..... 125 tons

Total feed to classifier..... 180 tons

Mesh	Sands	Overflow
+20	3.0	...
+40	5.5	...
+60	7.5	...
+100	37.0	...
+150	...	3.0%
+200	41.0	7.0
-200	16.0	90.0

Standard Duplex Classifier in closed circuit with tube mill, Chilean mill used for preliminary grinding.

Original feed or discharge of Chilean mill..... 133 tons
Sand return from classifier or tube mill feed..... 93 tons

Total feed to classifier..... 226 tons

Mesh	Chilean Mill Discharge	Tube Mill Discharge	Classifier Sands	Classifier Overflow
+20	9.7%	...	...	...
+40	16.2	...	...	...
+60	14.7	...	...	...
+100	12.8	8.7%	83.6%	4.9%
+150	9.4	10.5	7.0	8.7
+200	6.0	11.4	3.0	10.3
-200	31.2	69.4	6.4	76.1

Standard Duplex Classifier in closed circuit with a tube mill. Original feed to classifier..... 150 tons
Sand return from classifier or tube mill feed..... 180 tons

Total feed to classifier..... 340 tons

Mesh	Total Feed	Sands	Overflow
+20	28.9%	26.5%	0
+60	21.2	35.2	0.8%
+100	12.0	14.0	1.0
+150	9.1	7.0	6.4
+200	4.0	4.0	12.6
-200	24.8	12.5	79.2

Material: Roasted ore.

Tonnage: 300-350 tons per day.

Dilution of feed: 3.5 to 1.

Mesh	Feed	Slime Overflow	Sand
+30	7%	...	10%
+40	10	...	14
+60	20	...	30
+80	5	...	7
+100	10	...	15
+150	5	2%	7
+200	7	4	10
-200	36	94	7

Duplex Extra-heavy Classifier 6 ft. in width in closed circuit with ball mill for coarse separation. Dilution overflow 3 to 1.

Original feed to classifier..... 381 tons
Classifier sands or ball mill return..... 855 tons

Total feed to classifier..... 1,236 tons

Mesh	Feed	Sands	Overflow
+6	0.3%	1.6%	...
+8	1.0	3.0	...
+14	5.6	12.6	...
+28	17.0	25.0	...
+48	26.2	33.4	0.7%
+65	11.0	11.4	3.6
+100	7.1	4.4	7.8
+200	7.0	3.2	1.8
-200	24.8	5.4	73.1

Power.—Mr. Wiard states the power required for driving any of the machines mentioned (Dorr, Akins, Esperanza) does not exceed 0.01 to 0.02 horsepower per ton of solids handled per day. This is certainly conservative as far as the Dorr classifier is concerned. It has usually been difficult to get measurements of power taken, as it is so trivial. The Desert Mill, however, reported a measured consumption of 0.66 horsepower (motor input) for 580 tons solids per day, which with normal motor efficiency will not exceed 1/10 of his low figure, and other data has indicated approximately 1/8 horsepower per 100 tons solids in feed.

Maintenance.—Without wishing to bore your readers with a discussion of points that may be considered largely matters of opinion, I desire to touch on several other conclusions reached by Mr. Wiard. He considers that for general attention and lubrication the Dorr will be the worst of the three machines discussed. This conclusion as compared with the Akins might readily be reached by one who has not operated the Dorr and has had his attention called to its numerous parts, but would not seem tenable against the submerged joints of the Esperanza.

A study of the details of construction of the Dorr will show that all parts moving on each other are raised well above contact with the pulp and, except the crank, all joints are in continuous tension so that if wear occurred no lost motion would result.

In actual practice, the attention for oiling, etc., required by any of the machines is extremely light, and with the careful system of grease lubrication on the Dorr, most operators have found it negligible.

As to wear and tear of rakes or moving means, Mr. Wiard considers the Akins will report the most, and thinks there will not be much to choose between the Dorr and the Esperanza. Theoretically, I should put the Esperanza far ahead of the other two on this point, one reason being that it has wear not only on the moving parts, but on the bottom as well, while the Dorr and Akins form a bottom of packed sand. I have very little data on this, but know that at one well-known plant in Ontario, grinding a very hard ore very fine, an Esperanza was installed after six Dorr had been running a year or more, and the superintendent advised me that he had been obliged to put in entirely new moving parts in the Esperanza, while the Dorr had had no repairs. He subsequently added two more Dorr to the plant, and wrote me: "I shall be very glad to give our experience with a drag classifier as compared with a Dorr classifier, as we have the drag classifiers working under exactly the same conditions as one of your long Dorr classifiers. The results of this experience are very much in favor of the Dorr type of classifier, both in regards to work done and repair costs."

While the belt and scraper type, which is undoubtedly very old, and was described by Scobery in 1904 as being used for tails dewatering, is not strictly an Esperanza, it is very similar and costs might be assumed to be analogous.

I had occasion a year ago to go into maintenance costs and obtained from one of the large well-known copper mills in Arizona the following:

DRAG MAINTENANCE	
Total tons.....	638,454 in 12 14-in. drags
Labor (upkeep).....	\$827.74
Sundry supplies.....	\$89.69
Shop charges.....	241.82
Belt.....	259.88
Scrapers.....	145.50
Total.....	\$2,064.63 = 0.3c. per ton.
Maintenance per month per drag.....\$28.70	

As compared with this we have a cost of 0.1 per ton on the oldest type of Dorr machine, the manufacture of which was discontinued eight years ago, but which is still in use at the Golden Cycle mill.

One of the largest Nevada mills has reported a repair supply cost of 0.03 cents per ton of original feed, which means approximately one-half that per ton of total feed.

Another mill reporting two and one-half years' operation gives a maintenance of 0.024c. per ton, while one the writer was associated with showed only one roller replaced in three years, and several rakes riveted.

The vital point that many people overlook is that these low repair figures mean much more in smooth operation of the plant than in actual savings.

It has been an interesting fact that on a fine feed 10-mesh and finer, the wear on the bottom of the scrapers was extremely small, as the following from the manager of a large Utah mill indicates: "I think the rakes on our Dorr classifier were in use fully five years and they showed no perceptible wear when we shut down. Very little sand went into the classifier coarser than 10 mesh."

With the ¼-mesh material now often fed the machines it has been very definite, although not enough to raise the maintenance figures.

Mr. Wiard states: "The Akins may often be started without digging out, while with the other two kinds this operation will be necessary."

If the settling box in any mechanical classifier is filled with hard packed sand, starting without loosening it will be very difficult. Users of the Dorr classifier

advise us that under normal loads the machine starts with no trouble, but when heavily loaded or a large amount of sand is run in after a sudden shut-down, it is necessary to raise the rakes before the sand becomes packed. The machine can then be started and the rakes gradually lowered to the normal position.

Mr. Wiard comments on the products from the three classifiers and states the Akins gives the cleanest sand, the Esperanza the cleanest slime, and the Dorr the poorest. This appears to me a generalization without actual comparative data which it is difficult to get. It is naturally too large a subject for thorough discussion at this time, but what information I have been able to get from comparative tests shows that with an equal amount of sand thrown into the slime, the Dorr classifier, with its varied means of regulation and sprays for washing the sand before its discharge, will give at least as clean sand as any other machine I know. As to the Esperanza making a cleaner slime, there is no theoretical reason to assume this, and the work at Nipissing, when product entirely passing 200 mesh was wanted, showed the reverse.

JOHN V. N. DORR.

New York City.

Probability and Chance in Screening

To the Editor of Metallurgical & Chemical Engineering

SIR:—On page 194 of the issue of Feb. 15 Mr. Edward S. Wiard has allowed a mathematical error to creep into his discussion of "Probability and Chance in Screening." The statement is as follows:

"A little reflection will show that the chances of a grain falling through the square (opening) are the ratio of the area of the inner square to the area between the inner square and the outer, or

$$\frac{l^2 - 2F/n + F/n^2}{2l^2/n - l^2/n^2}$$

which reduces to $\frac{2n-1}{2n-1} = 1$. (In the original there

were two typographical errors, which I have corrected.) The inverse ratio fixes the chance of a grain *not* passing through, and is also a measure of the number of squares a grain will have to pass over before falling through."

Let us assume the correctness of Mr. Wiard's argument as to the size of the inner square under the conditions of the problem stated by him. If a number of grains of certain size strike the larger square indiscriminately, and can fall through only if they fall within the area of the smaller inner square, the chance for any particular grain to fall through is given by the ratio of the area of the inner, or *effective*, area to the *entire* area under consideration. Stated mathematically, using the same symbols used in the original article, the formula is $\frac{(l - l/n)^2}{l^2}$, which equals $(1 - 1/n)^2$. It

will be seen that the formula is independent of the absolute size of the opening, depending only on the ratio of the grain size to the opening. The value of the probability of a particle falling through ranges from 0 when $n = 1$, or the grain is as large as the opening, to 1, or certainly, when $n = \text{infinity}$, as with an infinitely small particle inner and outer squares coincide; in other words, the entire area becomes effective. The probability can never exceed 1.

The chance for a grain not falling through is not the reciprocal of the probability of its falling through, as stated by Mr. Wiard, but is equal to unity minus the probability of falling through. There are two alternatives, falling through and not falling through, and as the grain under consideration must follow one of these courses, the sum of the two chances must be 1 or cer-

tainty. This value of the chance of not falling through also represents the proportion of grains remaining in the oversize after passing over one square. After passing over two, the remainder will be the square of this value, and after passing p squares it will be the original remainder raised to the power p . This shows that by increasing the number of openings passed over, the screening can be brought nearer perfection, but 100 per cent efficiency can only be reached with an infinite number of holes, although it can be very closely approximated.

The following table gives the values of the probability of falling through, of not falling through, and the amount of the remainder on the screen after passing over various numbers of openings:

Value of n	Probability of Not Passing Through		Remaining in the Oversize After Passing Openings				
	Passing Through	Not Passing Through	1	2	4	8	16
1	0.000	1.000	1.000	1.000	1.000	1.000	1.000
2	0.250	0.750	0.750	0.563	0.316	0.100	0.010
4	0.5625	0.4375	0.438	0.191	0.037	0.013	0.0002
8	0.766	0.234	0.234	0.055	0.003	0.000	....
16	0.879	0.121	0.121	0.015	0.0002	....	....

There is no expression possible for the number of openings required for perfect screening, as perfection is the limit that can never be reached under the assumed conditions. The expression for the remainder as given in the above table is

$$\left(\frac{2n-1}{n^2}\right)^p = R = 1 - E,$$

where R is the amount remaining in the oversize after passing p openings, and E is the efficiency of the screening operation. From this, $E = 1 - \left(\frac{2n-1}{n^2}\right)^p$, and

$$p = \frac{\log(1-E)}{\log \frac{2n-1}{n^2}}$$

On page 195 Mr. Wiard apparently recognizes the correct statement of the probability of a grain falling through, as under the heading "Interpreting the Chance Law" he states:

"Let x be the area of the chance inner square for any particular sized grain, and y the area between the inner and bounding square of the aperture. Then of A grains approaching a line of apertures of the lower limit of size, the fraction $x:(x+y)$ will pass through the screen and the fraction $y:(x+y)$ will remain in the oversize."

NATHANIEL HERZ.

Lead, South Dakota.

Perfect Heat Insulation

To the Editor of Metallurgical & Chemical Engineering
SIR:—In your issue of Feb. 15, page 227, second column, top, Mr. Boeck has referred to a paper of mine which was published in your issue of February, 1912, but by what is apparently an error in transcribing I am represented as having said something which in fact would be foolish.

The word "furnace" should have been "electrode." Perfect insulation in a furnace wall which is exposed on the outside is an impossibility. The perfect insulation which I referred to in the article to which he refers is that which could be maintained between a conducting electrode which passes through the walls of a furnace, and the wall immediately surrounding it, in which case no heat would flow from the electrode to the walls or the reverse.

This may be accomplished, as I think will be acknowledged by everyone, by having the heat gradient in that portion of the wall which is next to the electrode, exactly the same as the heat gradient in the electrode itself; the evident principle being that if there is no dif-

ference of temperature between two adjacent parts, there will be no flow of heat from one to the other. This is a method of insulating and not strictly speaking an insulator.

This, together with one other case, is the only possible way that I know of for producing perfect heat insulation; but the principle is evidently not applicable to making furnace walls insulate perfectly, which he reports me as having said, except if the outside of the furnace wall be heated to the same temperature as the inside, which would defeat the purpose of the wall.

In this connection, however, I may add that at the time of these discussions I pointed out that in a way the latter result might be approached at least for electric furnaces by heating the outside of the furnace as hot as convenient by means of a cheaper heat than electric heat; that is by placing an electric furnace, including its walls, inside of a gas heated furnace. Some time thereafter I noticed that a patent was taken out by some one else for this method of improving the heat insulation of electric furnaces.

CARL HERING.

Philadelphia, Pa.

Non-Ferrous Metal Market

Saturday, March 11.—The features of the market during the past two weeks have been the dullness in spelter and its consequent decline of about 3 cents per lb., and the British Government regulation to stop speculating in all metals entering into ammunition manufacture. This regulation which prevented sale of all metals except tin on the London Exchange went into effect on March 2, and had a depressing effect on our market. It was withdrawn on March 6, however, when trading in London was resumed.

Copper.—The copper market has been dull but has not developed any inherent weakness although spot prices are a trifle lower. Electrolytic and Lake are quoted at 27¼c. Exports for February were 20,548 tons. The strikers at the American Brass Company started to return to work on Feb. 28, with a 15 per cent increase.

Tin.—Spot tin has been very scarce and is now almost unobtainable. The future market is very strong. On Feb. 28 the price had risen to 50 cents but dropped to 46 cents on March 2, partly on account of the British regulation stopping trading in London. It has since risen again and is now quoted at 56 cents. Deliveries aggregating 6388 tons were made in February, which is a record.

Lead.—Lead is very strong and has been in good demand. The Trust raised the price to 6.40, New York, on March 3, and to 6.60 on March 7, which is now the quoted price.

Spelter.—Spelter, which was quoted at 20.50 two weeks ago, is now selling spot at 17.75. This decline was the result of dullness in the market. If there has been much business done in the last two weeks it is not generally known.

Other Metals.—Virgin aluminium is very scarce and is quoted at 62 cents. Antimony is likewise hard to obtain and has remained steady at 44.50. Silver varied about one-fourth cent and is now quoted at 56¾. Platinum remains nominal at \$88 per oz. Quicksilver is quoted at \$260 per flask.

The Iron and Steel Market

The steel market continues to show a sharply advancing tendency, though it is possible that the general average has not moved up altogether as much in the past fortnight as would be indicated by the pace in

February. On the last day of that month new discount lists were issued by the pipe mills, advancing black iron and steel pipe one point or about \$2 a ton and galvanized two points, while boiler tubes were advanced one point. On March 1 came the expected advance of \$2 a ton in wire products. Skelp has gone up about \$4 a ton, in sympathy with the advances in pipe on Feb. 15 and Feb. 29, as well as the advance in plates of \$5 a ton just after the middle of February. There have been sharp advances in various descriptions of manufactured steel, including shafting, rivets, etc.

The laws of steel market movements have been complex and confusing enough in the past, yet when one attempts to analyze the present situation he sees by comparison that the movements of the past were more or less regular. What is particularly startling at the present time is that there are no influences exerting any control. That may appear to be a rash statement, yet it can be supported by considerable argument. While our reasoning may not be altogether precise, we submit it is fairly accurate in substance, that normally the two great controlling elements are the physical and the psychological. The physical determines how much steel will be put into consumption, the question whether the consumption or the application of a given piece of steel will "pay," being really a physical problem, while the quantity that can be produced is usually considered a physical problem. The mill manager and the workmen are expected to do their best at all times.

What we have called the psychological controlling influence is of course the mental attitude of the two parties to a market transaction, the seller and the buyer.

Now as to the physical, it is to be observed that the steel being shipped at this time from the mills and passing, one may presume, into use, is not being paid for at present market prices. Orders are being filled on contracts that were placed more than six months ago. Even disregarding the fancy prices now being asked, and paid as to a limited tonnage, for prompt shipment, and taking as basis the prices asked by large mills for delivery far in the future, if the average advance that has occurred to date in this movement, which started at the beginning of 1915, be taken as unity, then the steel now being shipped is invoiced at an average price representing only between one-fourth and one-third of that advance. It may be concluded that the steel now passing into use or ultimate consumption carries only a small part of the increment in cost that will obtain later if the market holds, even if it does not continue advancing. Therefore, the physical control as to whether high priced steel will pass into consumption with the same freedom as moderately priced steel, is not yet exercised. It is yet to be observed in the future how that physical control will be exercised.

As to the mental, what is in the minds of the two parties, the buyer and the seller, it is obvious there is no control. In the past the sellers of steel have placed a curb upon rising tendencies and have quite freely taken the public into their confidence, to the effect that they would not permit prices to pass above what was considered a safe and reasonable level. To-day they do not maintain such an attitude. Certain legal developments have given them more freedom, and they became imbued some time ago with the belief that steel market strength would last during the war, but in all probability no longer, hence there is no regulating influence that could be exerted, in the matter of prices, to prolong the period of prosperity and active demand. The seller of steel simply adopts the position that the buyer is making the market. It is what would be called in the nomenclature of ordinary times a "sellers' market," but really it is what might be termed, if the nomenclature permitted, a "buyers' market." The typical buyer

is regarded as one who beats the price down when circumstances give him a measure of control. To-day he is pushing the price up.

What, then, is the mental attitude of this buyer? He has no precedent. In the past the seller of steel has taken care of him, advancing prices by easy stages, and to no level comparable with the present, for the advance in finished steel products, delivery at mill convenience is now a score of dollars a ton against, say, half a dozen dollars in the preceding three great movements of the steel market, while furthermore with practically every advance the seller has given the buyer an additional contract, for farther and farther delivery, whereas at this time forward delivery contracts are very hard to make. The seller does not look out for the interest of the buyer as he did in the past, and the buyer has no precedent to guide him. He does not know, as a rule, anything about what actual ultimate consumption of steel will be at high prices, and more or less at random he has adopted the practice of bidding for steel, or even of seeking protection as to deliveries at whatever price the mill may choose to name later. The buyer is in a panic, a state of mind described as that of unreasoning fear. There may be the best cause for that fear, but the reasoning is to a large extent absent.

With no important control, physical or mental, exerted at the present time, the steel market's future could not well be more in doubt. The majority of observers expect the pressure for steel to continue throughout the year, and indeed to increase. There are some who expect a break in prices before July 1, perhaps more than one break, for if a break does occur before the end of the war the downward movement will probably be as spectacular as the upward has been, with probably this difference, that the decline will not be continuous, but will be interspersed with periods of recovery. One can reasonably expect such recoveries because there is a "short interest," using stock market parlance, accumulating by projects being postponed when promises of return on the investment are good, but not sufficiently good to warrant outlay at the highest prices.

Pig Iron

The buying movement in pig iron which began about the middle of February has gained some momentum and the market of the past fortnight may be described as decidedly active, with a slight rise in prices. The advance in pig iron from its low point of a year ago has been moderate compared with the advance in steel, both raw and finished, and buyers of pig iron have reason to fear spectacular developments in the market, with practically no limit to advances, while declines could at most only be moderate. The buying is almost exclusively for the second half of the year, buyers being well covered already to July 1. We quote: No. 2 foundry, delivered Philadelphia, \$19.75 to \$20; f.o.b. furnace, Buffalo, \$18 to \$18.50; delivered Cleveland, \$18.80; f.o.b. furnace, Chicago, \$18.50; f.o.b. Birmingham, \$15 to \$15.50; at valley furnaces, 95 cents higher delivered Pittsburgh; Bessemer, \$20.50 to \$21; basic, \$18.25 to \$19; foundry, \$18.50 to \$19; forge, \$18 to \$18.50; malleable, \$19 to \$19.50.

The contract price on English ferromanganese was recently advanced from \$150 to \$175, seaboard, and only a limited tonnage seems available for fourth quarter, while delivery would be quite uncertain. An acute scarcity of spot alloy developed early in the month, and the needs of smaller users, who do not contract for forward deliveries as do the large consumers, could not be met at rational prices, relative to the contract market, and sales have been made of small tonnages at \$300 and upward, with no limit to the possibilities of the next few weeks.

Steel

While the market turnover in unfinished steel is necessarily limited, as the ordinary consumer could not afford to pay prices asked, and must depend on his contract deliveries, at much lower than current prices, there are exceptional cases arising with greater frequency in which the buyer can afford to pay prices asked. For instance, blue annealed sheets, 10 gage, are selling at a higher price than box annealed, 28 gage, and so the market of the one can afford to pay a higher price than the maker of the other. As another instance, there are steel interests, ordinarily self-contained, that can sell forging billets at very high prices, and can afford to buy soft steel, to fill orders for ordinary finished products, at what represents a loss when the conversion cost is added, but which allows another branch of the sales department to score a large profit. We quote as fairly representative of a somewhat elusive market: Bessemer billets and sheet bars, \$40; open-hearth billets and sheet bars, \$42 to \$44; forging billets, \$60 to \$70; rods, \$55; high carbon rods, \$75 to \$85.

Finished Steel

Regular prices given below are f.o.b. Pittsburgh, unless otherwise noted; where a range is given the lower price is for delivery at convenience of large mills, and the higher for early delivery, from such mills as make a practice of not selling far ahead.

Rails, standard sections, 1.25c. for Bessemer, 1.34c. for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 2.35c. to 3c.

Structural shapes, 2.25c.

Steel bars and bands, 2.25c. to 2.75c., base; steel hoops, 2.50c., base.

Iron bars, Philadelphia, 2.559c.; Pittsburgh, 2.40c. to 2.50c.; Chicago, 2.15c.

Plain wire, 2.25c., base; wire nails, \$2.40, base; galvanized wire, 2.95c.; painted barb wire, 2.55c.; galvanized barb wire, 3.25c.

Award of Nichols Medal

Meeting of New York Section of American Chemical Society

At a meeting of the New York Section of the American Chemical Society held on March 10, at the Chemists' Club, the Wm. H. Nichols gold medal was presented to Dr. CLAUDE S. HUDSON of the Bureau of Chemistry, Department of Agriculture. The chairman Dr. T. B. Wagner presented the medal and gave a biography of Dr. Hudson's life. Dr. Hudson then presented a lengthy paper on the "Acetyl Derivatives of the Sugars" describing research work in which he has been engaged and illustrating it by numerous large diagrams. Following this paper a very interesting account of the development of the Bureau of Chemistry and its work was given by Dr. Carl L. Alsberg, chief of the Bureau.

The election of officers for the coming year resulted in a tie vote for the chairman between Dr. J. M. Matthews and Dr. K. G. Falk. The deciding vote of the chairman was cast in favor of Dr. Matthews. Dr. F. J. Metzger was elected vice-chairman and Mr. Charles F. Roth secretary-treasurer.

Corrosion

Joint Meeting of A. I. E. E. and A. E. S.

The problem of corrosion was discussed in two very interesting papers presented at a joint meeting of the American Institute of Electrical Engineers and the New York Section of the American Electrochemical Society on March 10, at the United Engineering Societies Building, New York.

The first was an A. I. E. E. paper on "The Influence of Frequency of Alternating or Infrequently Reversed Current on Electrolytic Corrosion," by Dr. Burton McCollum and G. H. Ahlborn. The second was an A. E. S. paper on "Corrosion and the Engineer," by Prof. W. H. Walker. This paper was read by Prof. W. K. Lewis in the absence of the author.

Prof. Walker after discussing the rather general lack of a clear conception of corrosion on the part of electrical and mechanical engineers took up a general discussion of corrosion.

Corrosion is an electrolytic phenomenon and takes place at ordinary temperatures only in the presence of water. Metallic iron electrically neutral interacts with two hydrogen ions present in the water and which carry electrical charges; an iron ion is produced which takes up the two electrical charges from the hydrogen ions and deposits two atoms of hydrogen.

The factors which influence the corrosion are:

First: The solution pressure of iron. When this is practically nil, as in the case of iron immersed in chromic acid solution, corrosion does not take place. The solution pressure may also be rendered negligible by the impression of an external emf.

The second factor is: The number of the hydrogen ions. The greater the concentration, the more rapid will be the corrosive action. Hence, in the presence of acids, corrosion is accelerated and in the presence of alkalies, it is retarded.

The third factor is: The ease with which the hydrogen ion reaches the iron. For example, an adherent film of iron oxide will protect the metal underneath. Such a film is undoubtedly formed in the case of the copper-steel and accounts for its remarkable resistance.

The fourth factor is: The osmotic pressure of the iron ions. This pressure is usually very small.

The fifth factor is: The deposition of hydrogen and its removal by the depolarizing action of oxygen. This factor is probably the most important of them all. If oxygen be completely removed from boiler feed water, the boilers will not pit nor corrode.

The following members participated in the discussion: Messrs. Alexander Maxwell, Philip Torchio, C. B. Martin, L. W. Chubb, A. S. Cushman (who offered a very interesting discussion), Maximilian Toch, James Aston, A. F. Ganz and F. N. Speller. Written discussion was also submitted by Carl Hering, J. L. R. Hayden, S. M. Kintner and Asa P. Way. A fuller report of the meeting is reserved for our next issue.

The sodium peroxide department of the Niagara Electrochemical Company (owned by the Roessler & Hasslacher Chemical Company) was damaged by explosion and fire on March 8. The plant will be rebuilt immediately and new apparatus installed and it is expected to begin deliveries again by May 1.

Electric Tin Smelting in Bolivia.—An interesting development in electric tin smelting is announced in the formation of the South American Electric Smelting Company, which has been organized to smelt tin ores in Bolivia. The new company will take over the equipment of the Standard Smelting Company, Pittsburgh, which was organized for smelting Bolivian concentrates and other tin bearing material in the Wile electric furnace. Three ten-ton Wile furnaces will complete the first installation in South America. These will be placed at different locations on account of the difficulty of shipping ores to one spot. It is expected that these furnaces will be in operation by June 1. Proposed legislation for exclusive smelting and water power rights in Bolivia was the cause of the formation of the new company. Minor C. Keith of the United Fruit Company is president and H. M. Keith is treasurer.

Recent Practice in Concentrating Colorado Tungsten Ores

BY H. C. PARMELEE

Taking them by and large the tungsten concentrating mills of Boulder County, Colorado, have not been inspiring examples of the art of ore-dressing. In fact, to the engineer visiting for the time in this most important tungsten-producing region of the country, some of them appear as marvels of poor construction and bad practice. A probable reason for this is to be found in the history of the industry. Before tungsten became an important product of the district, gold and silver mining ventures had been as numerous as they were unsuccessful. Many mills had been constructed to demonstrate a variety of processes, and a liberal assortment of machinery had been purchased. The result was that when tungsten became recognized as the greatest mineral asset of the county, mill buildings and equipment of a sort were not lacking with which to commence operations on a small outlay of capital. Thus the early tungsten concentrators followed local customs and traditions and adapted themselves in great measure to existing conditions, proceeding along lines not in accord with what would have been considered best practice.

In a previous series of articles¹ the writer discussed the problems of tungsten concentration, described the existing practice at all of the mills and gave some data bearing on the magnitude and importance of the Boulder County production as compared with that of the United States. The county still holds its premier position among tungsten-producing districts of this country.

At the time the articles mentioned were written, the newest mill was that of the Primos Company, the features of which were crushing in stamps, and concentration on Wilfley tables, vanners and stationary canvas plant. The latter had an area of about 10,000 sq. ft. The other important mill was the Wolf Tongue, which was the first to adopt the jig and minimize the use of canvas tables, but it was not a model plant. In fact there was at that time no mill in the district working along lines meriting general approval.

Criticism of Grinding Methods

Adverse criticism of the milling practice has been leveled mainly at the use of stamps for crushing. The

basis for this will be found in considering the physical properties of ferberite, the principal tungsten mineral in Boulder County ores. This mineral is brittle and friable, and has a specific gravity of 7.2-7.5. The gangue is tougher and lighter. Thus when the ore is crushed in stamps, the heavy friable mineral remains too long in the mortar and is ground finer than necessary, producing a needless amount of slime. By the time the tough gangue is crushed fine enough to pass the screen, the soft heavy mineral is much finer, and some of it is of the consistency of paint. The criticism holds good for any grinding machine that affords a settling pocket for the collection of heavy mineral.

With such preliminary treatment, an elaborate slime-recovery plant follows as a necessity; but if the ore were crushed in a different manner, as by rolls,

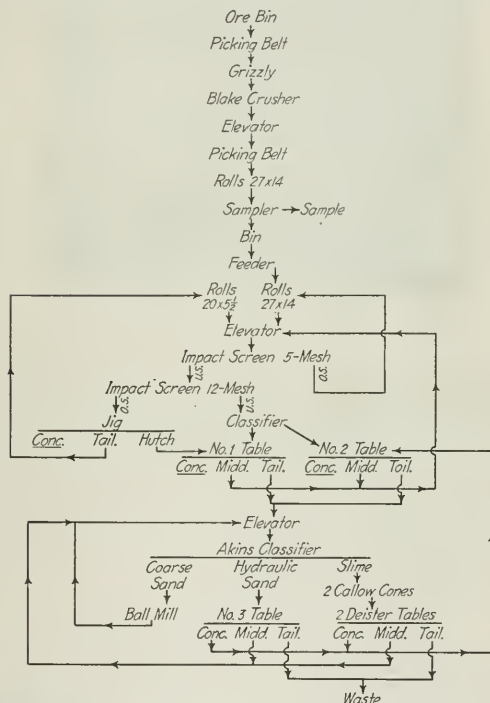


FIG. 2—FLOW-SHEET TUNGSTEN CONCENTRATOR

the ore-dressing scheme would be altered. By the use of jigs a large part of the mineral would be recovered in coarse, high-grade form, and on regrinding the jig tailing and classifying the pulp the balance could be recovered in a large measure on sand and slime concentrating tables of approved types. Stationary canvas tables might be dispensed with entirely, and in any event very little reliance need be placed in them.

In making these comments it is not forgotten that there are some ores in the district in which mineral is finely disseminated, wholly unsuited to jigging and extremely difficult to concentrate by any means. The suggestion of roll-crushing and jigging for these tungsten ores is not new and has been made frequently, but until recently no opportunity was afforded to put it into practice.

The present demand for tungsten, however, and the attractive prices offered for concentrates have stim-



FIG. 1—CONCENTRATING MILL, BOULDER TUNGSTEN PRODUCTION COMPANY

¹This journal, July and August, 1911.



FIG. 3—SCREENS AND JIG

ulated production as never before. Boulder County has seen more activity than for several years past. Prospectors have been numerous and diligent; some lessees are enriching their output with hand jigs; one or two old idle mills have been pressed into service or are being remodeled for concentrating purposes; and at least one new one has been built. Prosperity is in evidence on all sides; buyers are plentiful and in active competition bidding for concentrates. It was under the stimulus of these conditions that the Boulder Tungsten Production Co. built the modern 40-ton concentrating mill shown in Fig. 1.

New Mill of Boulder Tungsten Production Co.

The structure was erected near the mouth of the tunnel through which the mine is worked, on a site just below the Nederland dam of the Colorado Power Co. The cost of the mill, fully equipped and running, was about \$18,000; and such is the state of the tungsten industry at the present time that within four weeks of the day the mill was started, and working only two shifts per day, its entire cost had been recovered in the value of products sold. And such a record was accomplished with mill feed averaging about 1 per cent WO₃ and sometimes less.

The coarse crushing, grinding and sampling equipment has a capacity of 75 tons, the balance of the mill 40 tons, per 24 hr. Electric power is used throughout. The flow-sheet, Fig. 2, gives an outline of the equipment and treatment, the features of which are roll-crushing, screening, jigging, hydraulic classification, ball-milling and table concentration. There are no stationary canvas tables. The only grinding machine in the



FIG. 4—AKINS CLASSIFIER WITH HYDRAULIC COMPARTMENTS

system that would afford a pocket or lodging place in which tungsten mineral might remain and be ground unduly fine is the ball-mill, and this is of the rapid discharge type. Furthermore, it receives only sand tailings from the concentrating tables, after free mineral has been removed. Otherwise all grinding is done with rolls, and after each reduction in size the pulp is dressed for the recovery of free mineral. All middlings are kept in closed circuit, and the only tailings rejected are those from the slime tables.

Roll Crushing and Sampling

Two short picking-belts are in use, one each before and after crushing to 1 in. The next reduction in size is by rolls to $\frac{1}{4}$ in., at which size the ore is sampled. The Vezin sampler first installed is to be replaced by a horizontal traveling-bucket sampler, which can be better adjusted to the local requirements. In this sampler the buckets are supported between endless traveling chains, and the quantity removed for sampling can be adjusted by varying the number of buckets or their rate of travel. The sample is delivered by gravity to the coning floor, which is covered with sheet steel. Here it is coned and quartered and finally ground for assay.

There is a storage bin for the $\frac{1}{4}$ -in. roll product

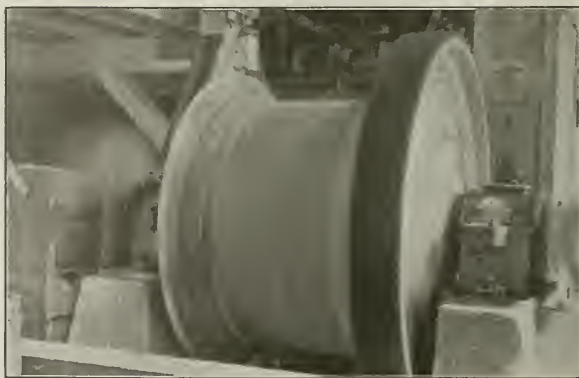


FIG. 5—BALL MILL, SCOOP FEED AND RAPID DISCHARGE

rejected by the sampling apparatus, and from this bin a plunger feeder supplies the rolls which crush to about $\frac{1}{8}$ in. This product is elevated and passed over two impact screens, 5-mesh and 12-mesh respectively, the undersize of the first going to the second. The 5-mesh oversize is returned to the rolls. The product, —5 + 12 mesh, is jigged, and the —12 is classified for table treatment.

Importance of the Jig

The jig is a useful machine in concentrating most Boulder County tungsten ores, and its omission in earlier mills is a point of adverse criticism. The great point in its favor is the recovery of a high-grade concentrate in coarse form. Compared with jigs in lead or copper mills, the two-compartment machine at this plant may seem to be doing little or nothing; but in all the local tungsten mills the output of concentrate is measured in pounds rather than in tons, and it is far better to obtain as many pounds as possible in coarse form than to grind the mineral to paint and endeavor to save it on canvas. At this mill the jig concentrate is recovered by skimming several times a day, by-passing the feed during the operation. No provision is made for continuous discharge of concentrate, as it does not accumulate in sufficient quantity. Jig tailing is reground in separate rolls and returned to the elevator and screens. The small amount of hutch product is sent to the coarse concentrating table, as mentioned below.

The jig is of the Harz type, running with $\frac{1}{2}$ -in. stroke at 240 r.p.m.. In the first compartment the screen is 12-mesh, and in the second 14-mesh.

For table concentration the minus 12-mesh pulp is classified in a two-compartment hydraulic spitzkasten, the products flowing to two tables. To the coarsest grade is added also the hutch of the jig. These two tables make finished concentrates; middlings which are returned to the screens, and sand-slime tailings which are treated in an Akins classifier. The latter machine, in addition to making the customary sand-slime separation by the revolving helix, is equipped with hydraulic hoppers at the lower end for the removal of fine sand from the slime. Thus the machine in this case delivers coarse dewatered sand for re-grinding, fine sand from the hydraulic hopper, and slime overflow.

Regrinding in Ball Mill

The coarse sand is reground in a ball mill, 4 ft. in diameter and 3 ft. long. This machine is of the mod-



FIG. 7—TRANSPORTATION OF TUNGSTEN CONCENTRATES, LOAD VALUED AT \$10,000

ern type with a discharge compartment containing radial lifters, separated from the grinding compartment by a grating. The grinding medium is 2-in. steel balls, and the lining is hard white iron. The ball-mill product flows to an elevator and back to the Akins classifier. It is the intention to grind all sand to minus 40-mesh, but as the mill is not always loaded to capacity the grinding may be as fine as 50-mesh.

Redressing Slime Concentrates

The fine sand from the Akins classifier is concentrated on a Wilfley table, while the slime overflow is thickened in two 7-ft. Callow cones and treated on two Deister slime concentrators. During the first month of operation these three tables made finished concentrates and tailings, and middlings which were returned to the classifier. Under those conditions five grades of concentrates were being made, as follows:

Product No.	Machine	Per cent WO ₃
1	Jig	60
2	No. 1 table	54
3	No. 2 table	45
4	No. 3 table	35
5	Deisters	28

Just recently, however, a change has been made by Mr. W. A. Kunkle, mill superintendent, which reduces the number of products from five to three and at the same time raises the average grade of all products without lowering the percentage recovery. This has been done by redressing products 4 and 5 on No. 2 table. Products 4 and 5 are low-grade mainly by reason of contamination with silica, and their retreatment gives No. 2 table a heavier load and permits a cleaner cut of finished product. Since the middling is in closed circuit, a high-grade product can be cut without fear of loss. The effect of the change has been to raise the grade of product 3 to about 50 per cent, at the same time increasing the quantity and eliminating the two low grades. Under the changed conditions the products are as follows:

Product No.	Machine	Per cent WO ₃
1	Jig	60
2	No. 1 table	54
3	No. 2 table	50



FIG. 6—SLIME CONCENTRATORS

At the present time the recovery is averaging 87 per cent. The importance of jigging is indicated by the fact that the first two products, from jig and coarse table, represent 85 per cent of the total recovery. Further, these concentrates are the highest grade products, although since the above-mentioned change was made there is really no low-grade concentrate coming from this mill. In fact it is safe to say that no mill in the district is excelling this one in percentage recovery, and that probably none is equalling it in average grade of total product. The best canvas-table concentrate will rarely exceed 40 per cent WO_3 , while under present conditions it is likely that nothing lower than 50 per cent is being made at the mill under consideration.

We are indebted to Mr. J. G. Clark, manager, and Mr. W. A. Kunkle, mill superintendent, for the information here presented.

Potash from Kelp

A Record of Handling Kelp in Commercial Large-Scale Operation

BY I. F. LAUCKS

The scarcity of potash, due to the war, has caused great interest to be taken in any of its possible sources. One of these is the growths of kelp on the Pacific Coast, about which there has been much written in the popular press, but very little authentic information in the technical papers, outside of data regarding the composition of the plants.

The United States Government has done considerable work on kelp, but practically all of it has been confined to analytical data on the dried material.

Before this year most of the companies attempting to develop the kelp industry have been of limited capital. Only lately have several concerns with plenty of money to carry their development through to a successful issue engaged in this industry, so that at the present time a limited amount of dried kelp is being produced, and we may shortly expect a considerable increase in this production.

The experience detailed in the following paper has been confined entirely to the kelp of Puget Sound, the species "*Nereocystis Luetkeana*." The author has had direct charge of large-scale operations, harvesting, transporting and drying this kelp, and any value which these observations may have is because they are records of actual experience. Outside of the composition of the plants, most of the experience would be applicable to California kelp as well.

COMPOSITION OF KELP

The green kelp plant is mostly water. This applies to most of the Pacific species, and especially to "*Nereocystis*."

Analyses have shown as high as 95 per cent water. The average is probably between 92 per cent and 93 per cent. A great deal of disappointment has been caused to several concerns in this locality, who accepted the estimate of the Department of Agriculture that ten wet tons would make one dry ton. While this probably applies to California kelp (*Macrocystis*), it certainly does not hold for "*Nereocystis*."

To compensate in a measure for the larger amount of water, the Northern plant has a higher content of potash in the dried material.

For analytical data on kelp the reader is referred to publications of the United States Department of Agriculture and the University of California Experiment Station, and especially to Bulletin No. 248 of the latter.

CONDITIONS OF GROWTH

The "*Nereocystis*" is an annual plant, that is, it grows anew every year. The young plants reach the surface of Puget Sound waters in May and June. Some hold to their moorings the whole year, but most of them are washed away by storms by the end of February or March. They are attached to the bottom by a "hold fast," resembling the root of a land plant, but having none of its functions, other than to serve as an anchor. The plant grows from spores or seeds, which are dropped in August or September. A bed of kelp should not be completely cut away before the seeding time, or it might not be renewed the next year.

The best beds are found where the bottom is favorable for attachment, as rocks or hardpan. They also need a strong tide current to renew them.

The stem of the plant extends from the bottom to the surface, and stretches out on the surface up to ten or fifteen feet at low tide. The stem is cylindrical, hollow, filled with air, with walls up to one-half inch in thickness, and grows larger toward the upper end, terminating at this end in a bulb sometimes nearly half a foot in diameter.

From the bulb extend leaves, like ribbons, several inches wide, which grow as long as twenty feet. Ordinarily the bulb floats on the surface. The leaves, however, having no air to buoy them up, are somewhat below the surface, except when a strong tide current is running. Sometimes, also, the whole plant is dragged below the surface by a tide current.

Some of the beds form a thick, tangled mat of plants over the whole surface. In others the plants grow in bundles or sheaves, with open water between each bundle. Up to thirty or forty plants may compose such a bundle. Often a bed of kelp will have a rock in its center, which increases the difficulty of harvesting, or it may fringe a rocky shore very closely, so that not all kelp beds are commercially available by any means.

The stem and leaves are both soft enough to cut very

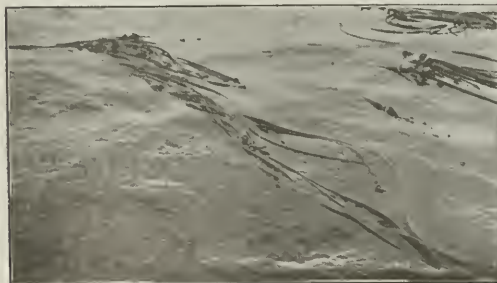


FIG. 1—NEREOCYSTIS



FIG. 2—KELP BED, PUGET SOUND

easily with a cutting edge having any motion, except the lower ends of the stems, which are considerably tougher.

HARVESTING

The great question in the utilization of kelp has always been the cost of harvesting. There was no reliable way of prophesying what it would cost to go out in the ocean, cut a plant below the surface of the water, get it aboard a scow and bring it back and unload it at a dock. As for the other features of the process, they were well known. Data on drying costs, leaching, crystallizing, etc., were available, but no one had ever before harvested a marine plant in hundred-ton lots.

There have been a number of different types of machines proposed for cutting kelp, including reciprocating knives, revolving blades, band saws, etc., but so far as the writer is aware the only method which has been tried in actual practice is that of reciprocating knives (like a mowing machine). These operate several feet below the surface of the water and may be made as wide as desired. A conveyor of some type is usually placed behind the knives to carry the cut kelp aboard the scow. After it is aboard it is generally chopped into shorter lengths by various machines, and piled either on the scow which carries the cutting mechanism or another scow alongside.

The harvester described herewith has a cutting capacity of one hundred tons of green kelp in six hours, at high tide. At low tide the cutting rate is considerably greater than this, as more of the plant is on the surface. Two men operate the rig, with the exception of unloading, in which extra help is required. They live aboard the harvester and do their own cooking.

One man stands on a bridge across the conveyor in front. It is his duty to watch for drift wood and keep it away from the conveyor with a pike pole. The other man has a general oversight of all of the machinery, and is available in emergencies. The kelp requires no actual handling at any stage on the harvester except in the unloading.

The cutter knife was made by joining two 6-ft. McCormick harvester knives end to end, making a 12-ft. knife, and slides on a guard bar made of a standard channel. The standard McCormick fingers and guards were attached to this bar. This knife in its cutting position is horizontal and 4 ft. below the surface. At each end of the horizontal knife is a vertical knife 5 ft. long, which reaches above the surface of the water. All three knives are driven together by an eccentric rod on the front end of the frame which carries the conveyor. This frame is made up of angles and channels, and carries the shafts and sprockets on which the conveyor runs. The conveyor is the same width as the cutter knife, and consists of a sprocket chain on either side, carrying wooden flights. Fish netting is fastened on the flights, and special attachments to pick up the kelp after it is cut.

As the kelp is cut it is carried back against the conveyor by the motion of the boat, and immediately picked up. The conveyor gathers up practically all of the cut kelp. Also all of the plants coming between the ends of the cutter knife are cut.

The conveyor is pivoted on a horizontal shaft so that it, with the knives, can be raised when cutting is finished. The conveyor dumps the plants into a bin at the bottom of which is a chopper. This chopper is 11 ft. long, and resembles a lawn mower. It was built by mounting six Ohio alfalfa cutter knives end to end on a shaft. The kelp is cut into lengths from 3 in. to 18 in., depending on the angle on which it falls into the cutter. This cutting is done merely for convenience in unloading, as it is entirely impractical to handle the full length stalks with their attached leaves.

From the chopper the cut kelp falls into another conveyor 18 in. wide, which delivers 20 ft. above the deck of the scow. The kelp falls in a heap on the deck, and as the heap grows in height it gradually flows outward until it distributes itself uniformly in a cone-shaped pile over the loading space, without any handling.

Gates are fastened to the sides of the scow and to the stanchions, which hold the kelp aboard. One hun-

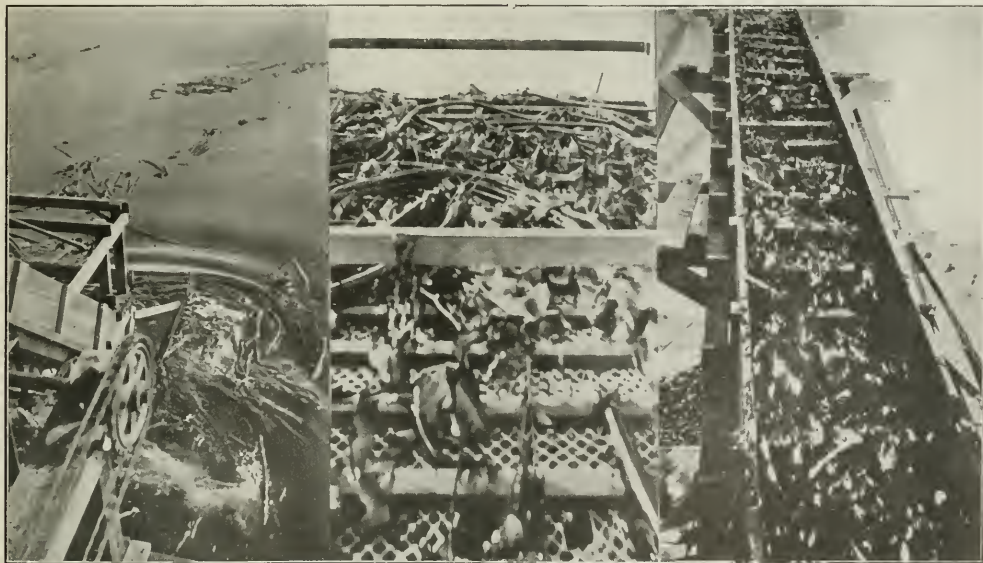


FIG. 3—SIDE VIEW CUTTER KNIFE

FIG. 4—KELP ON CONVEYOR FROM WATER

FIG. 5—KELP ON CONVEYOR FROM CHOPPER

dred tons of kelp will make a pile 8 or 10 ft. deep in the center and 5 or 6 ft. at the sides.

The scow is 90 by 28 ft., and 6 ft. deep. The machinery and living quarters take up 30 ft. forward. Fifty-five feet aft carries the kelp, and has a capacity of 200 tons. A 20-hp. Fairbanks Morse gas engine drives the entire rig.

In fairly quiet water the tug is tied alongside the scow, as it can be steered more positively in this position. In rough weather the tug takes a line from the forward corner of the scow, so that the scow stands at an angle to the direction of the tug. In ordinary weather a 60 to 80-hp. gas boat is sufficient to handle the scow and tow it back and forth at a rate of five to six miles per hour. During cutting the scow is moved as fast as possible by the tug. The kelp impedes the motion both by its resistance to the scow and tug and by entangling in the propeller of the tug.

During all stages of tide, except slack water, the current strings the plants out in fairly parallel lines. The most efficient cutting is done when the scow is running in the same direction as the plants. It makes little difference whether running with or against the tide. In small beds considerable time is lost in turning around, which must be done outside the bed. In larger beds the harvester can be turned inside the bed, so that cutting is not interrupted.

The harvester described has been operated in fairly severe weather conditions, with waves running so high that they continually broke over the forward deck of the scow. Such weather does not materially affect the speed of cutting.

The cost of cutting is mainly composed of the towing charge. This can be reduced considerably by mounting the cutting machinery on a self-propelled barge. In such an arrangement the same crew which at present is required on the tug could operate the entire harvester. Such a boat would have a further advantage of being more easily and positively handled.

COST OF HARVESTING

The costs herewith given are from actual operating figures. They are based on gathering 100 tons every 24 hr., that is, making one round trip per day between plant and beds.

	Per day
Labor—	
One man	\$3.00
One man	2.00
Provisions	1.50
Distillate and oil for power.....	1.50
Tug	30.00
Interest and depreciation.....	5.00
Total per day for 100 tons.....	\$43.00
Per ton	.43

The above cost holds for a distance of about twenty miles between the beds and the plant. For shorter or longer distances the cost is proportionately decreased or increased, as a smaller or larger tug is necessary. It will be noted that 30 cents per ton of the above cost is the towing charge.

The plan has been proposed of mounting the cutting machinery on one scow and carrying the load on another. The two would be lashed together during cutting. This idea appears impractical from the writer's experience. The handling of one scow by a tug in a kelp bed is hard enough without complicating matters by adding a third unit. In rough weather it would be very difficult to keep the two scows side by side. The harvester can be built for about \$6,000, including the hull.

UNLOADING

Two methods have been tried out, by hand labor and by the use of a drag scraper. The plant has a conveyor running out into the water, at a slope of 2 in. per foot, and long enough so that the outer end is under water at low tide. The scow can therefore always be laid alongside of some portion of this conveyor at any stage of the tide. The conveyor is simply a trough 3 ft. wide with a coil chain, to which are fastened 2 x 4-in. wooden flights, dragging along the bottom. The gates on the sides of the scow are hinged on the deck line, and when the scow is laid alongside the conveyor, are let down to form chutes from the deck of the scow over to the conveyor trough.

As the kelp is piled up 5 or 6 ft. deep at the sides of the scow, and is quite slippery, a considerable amount of the load can be slid off as soon as the gates are lowered with very little labor. The balance is then slid across the deck to the chutes by hand. Scrapers resembling a snow shovel or scraper are the handiest tool for hand unloading. The deck is very slippery, and a scraper slides easily. The men need corked shoes to prevent their slipping. Six men unload one hundred tons of kelp in six hours by this method.

We have tried the use of drag scrapers to move the kelp across the deck to the chutes. A 7-cu. ft. scraper handles several hundred pounds of kelp at one load. We discontinued this method of unloading temporarily because of lack of a winch to properly wind the scraper drag line.

The cost of unloading by hand is:

Four additional men at 25c. per hour, 6 hr. each.	\$6.00
Power	0.35
	\$6.35
Per ton	\$0.063

The power cost above includes conveying a distance of 320 ft. along the dock with a raise of 35 ft. to the bin, done by the same conveyor mentioned above.

We have designed a system of conveyors to be installed on the deck of the scow, which will unload it without any additional labor cost, the two men operating the scow also operating these conveyors. This will reduce the cost of unloading to less than 1 cent per ton.

CONVEYING

The cheapest and most satisfactory type of conveyor is the chain conveyor with wooden flights and either double or single chain. The kelp is slippery enough to lubricate the trough, so that the power requirement is low. Bucket elevators and screw conveyors have also proven satisfactory.

BINS

The bin at the plant under discussion has a bottom slope of 1 in 2.66 and is lined with rough lumber. This



FIG. 6—100 TONS KELP ABOARD HARVESTER

slope is just sufficient to cause the kelp to slide very slowly as it piles up at the upper end. In smooth metal-lined chutes kelp will just slide on the same slope when dropped into the head of the chute periodically as the discharge from a conveyor. When it accumulates in such a chute it slides readily.

Bins should be water-tight with provision for drainage to the dryer. When cut kelp is stored in a bin its own pressure is sufficient to squeeze out considerable liquor, which carries potash in direct proportion to its weight. After the second day in warm weather the kelp begins to decompose, and the loss of liquor is then much greater.

Cut kelp piles to a depth of a foot or two averages 40 lb. per cubic foot. When piled to a depth of 6 or 8 ft. as in a bin it is compressed and weighs as much as 60 lb. per cubic foot.

Drying

The direct-heat rotary dryer appears to be the most satisfactory type of dryer for kelp. It is necessary that the kelp be reduced to a uniform size before being fed to a rotary. That is, the leaves of kelp are very thin and present a great surface in proportion to their weight, while the stems are thick and fleshy. If fed to a rotary the leaves are quickly dried, while the stems come through so wet that free liquor is still present, and this happens with a dryer as long as 60 ft. These consequently have to be returned several times. If, however, the whole feed is shredded, then the drying is nearly uniform and very little, if any, of the product has to be returned. The product of the dryer with such a feed is fine enough so that it needs no further reduction to mix with other fertilizer materials.

As kelp carries about 2 per cent of nitrogen, under certain circumstances it is worth while to take precautions to prevent loss of nitrogen by burning in the drier. This can be done by feeding the green kelp at the fire end of the drier and regulating the feeding so that the moisture content of the product is between 5 and 10 per cent.

The dust problem in drying is a serious one, and a drier must be provided with efficient dust collectors. As much as 20 per cent of the weight of the product has been collected from the dust chambers in test runs. The method of spraying the dust with water and settling and redrying the product, which is in common use in fertilizer drying plants, cannot be used with kelp because of leaching the potash. Large chambers where the velocity of the air is much retarded are efficient.

In sacking and handling the dried product the dust is also very troublesome, as it is very pungent and irritating. Men working in it need to be provided with respirators. It also leaks through ordinary fertilizer or sugar sacks very easily. A paper-lined sack is best. The sacked material will weigh practically the same as fish meal.

The capacity of a 50-ft. drier is stated by manufacturers to be 3.6 tons of water per hour. This amounts to 3.9 tons of green kelp. Test runs have proven this estimate to be substantially correct.

Oil is the most economical fuel for the kelp fields of the California coast. In the Puget Sound district there is available an immense amount of waste wood from the lumber mills. As most of these mills are located on tide water and many of them very near the kelp beds, this cheap fuel makes a very favorable condition for the utilization of Puget Sound kelp.

By "hogging" or shredding this waste wood it can be burned with as low a labor cost as oil. It can be readily transported to any desired point by scows. The wood ash carries some potash which can be mixed with the dried kelp.

For reducing the green kelp to uniform size for feeding to a rotary, the Williams hammer type mill has been found very satisfactory. The product is very finely comminuted, its appearance being best described by the term "chewed up." Considerable liquor is set free by this shredding. Shredding in corrugated grooved rolls, with one roll running considerably faster than the other, has not proven satisfactory. The pieces tend to flatten out and are not sufficiently shredded. Other types of machines may be found satisfactory for this purpose, but the two above mentioned are the only types we have had opportunity to try. For grinding the dried product the hammer type mill is also very satisfactory. Factory tests of other types, as disks and rotary knives, have also been favorable. As before mentioned, if the feed is ground the product will need no further grinding. Large pieces of kelp stems dry to leathery consistency. These grind readily in a hammer mill.

As before mentioned a large percentage of the water in kelp squeezes out under its own pressure, when piled to any depth. This may also be squeezed out mechanically. Hand tests have squeezed out as much as 75 per cent of the water, and with it 75 per cent of the potash content. A machine of the type of the hydraulic press or a filter press would do better than this, but the labor cost would probably be prohibitive.

A trial of a 36-in. screw press was unsatisfactory, very little juice was squeezed out. The kelp fed had however already lost some of its water in shipping, so that this might not hold for fresh kelp. Rolls squeeze out some water but it is difficult for rolls to nip pieces of kelp unless they are set to at least $\frac{3}{8}$ of an in. apart, so that their squeezing action is much lessened.

If a cheap means can be developed for squeezing out part of the water, this water might be more economically evaporated in a multiple effect evaporator. The liquor, however, contains considerable organic matter both in suspension and in a colloidal solution. This might seriously affect the working of such an evaporator.

Patents are pending to Falckenburg & Laucks for a method of piling kelp in high towers, allowing it to partially decompose and squeezing the liquor out by its own pressure. The liquor would then be run to shallow ponds and allowed to evaporate by sun and air. The organic residue would be dried artificially. This method is applicable to hot, dry climates.

Kelp dries very readily when spread out in a very thin layer in the sun and air. Each plant must practically be kept separate by itself. If two are superimposed, the lower will not dry. If too close together drying is very slow. The labor cost of spreading and collecting and the acreage necessary make this method prohibitive.

The cost of drying will vary between 25 and 50 cents per ton of green kelp, depending on the fuel used, cost of power, size of plant, etc.

It is not necessary to go further than the dried kelp to obtain a marketable product. The potash and nitrogen are saleable on a unit basis. If there is a local market for these for fertilizer purposes, it would probably not be advisable to carry the operation further. If, however, the market is at some considerable distance with high freight rates, it is more profitable to concentrate the valuable ingredients and save freight charges on the valueless ingredients, as the sodium chloride and non-nitrogenous organic matter.

Assuming 28 per cent chloride of potash and 2 per cent nitrogen, in the dried material, about 60 per cent of the weight is practically valueless. If the material is shipped from the Pacific coast to the Atlantic by

water, the nitrogen will just about pay the freight by water in ordinary times. If the potassium chloride is concentrated from the balance, the nitrogen can be sold in the Pacific coast, and 70 per cent of the freight saved on the potash. The latter plan will be more profitable, except when the price of potash is very high, when the necessary loss of potash in leaching and purifying may counterbalance the saving in freight.

There has been some objection by fertilizer dealers that the nitrogen of kelp was not in the available form. When measured by the ordinary empirical methods for determining the availability of nitrogen it does not show a high availability. The methods used, however, are adapted to materials whose nitrogen content is much higher in proportion to their total organic (reducing) matter than is the case with kelp. If the method is altered to fit the changed conditions of kelp, the nitrogen is shown to be as available as other nitrogenous fertilizing materials and this has been borne out by all crop tests. In addition the high organic matter of kelp is valuable in furnishing humus to soils.

There have been a number of proposals for obtaining pure potassium chloride (and sulphate) from dried kelp. The dried material is readily leached, yielding a high percentage (95 per cent) of its potash contents to counter-current leaching. The potassium chloride can be readily separated from the sodium chloride by crystallization after several methods. There is no difficulty in obtaining as high as 95 per cent potassium chloride in the first products of crystallization.

It has been proposed to dry-distill, or retort the dried kelp, recovering the nitrogen as ammonia from the gases (along with acetone, creosote, etc.), and to leach the residue to obtain the potash. This will probably fail because so far the yield of ammonia has been very low while the cost of the method is high. The ammonia is the only gaseous product of any importance.

Most processes for recovery of the potash in fairly pure form, also take account of the iodine. This is left in the mother liquors after crystallizing out the potassium and sodium and can be obtained by ordinary methods for iodine recovery. It is stated that iodine recovered from Japanese kelp is a considerable factor in the United States market.

There is one other product of kelp which shows some promise of being valuable. This is the colloid, glue like substance called algin, which is present in most Pacific coast species. A number of uses have been proposed for it, but a considerable amount of research and development is necessary before any profits can be calculated from this source.

With the present high price of potash, the drying of kelp is a very profitable business. Such conditions will enable the industry to get a start and work out its problems. With normal prices of potash, kelp must be worked in plants of large capacity, well designed, with a minimum of labor, and every possible economy effected. All of the profitable by-products must be saved. It would seem unlikely that the price of potash will be lower for some time than it was before the war. If the price remains above \$35 per ton for 80 per cent muriate of potash, kelp can be worked at a profit in a properly designed plant.

Falckenburg & Laucks,
Seattle, Washington.

Metallurgical Progress in Peru

In a paper by MICHEL FORT, presented before the Second Pan-American Congress in Washington, D. C., an interesting account is given of recent progress in metallurgical practice in Peru.

The metallurgical industry in Peru is only about

twenty-five years old, and has developed rather slowly. Before 1889 gold washing and occasionally lode mining were practiced by very primitive methods, and amalgamation of silver and gold ores by the patio process was used to some extent, especially in Cerro de Pasco.

In 1889 the author of this paper started at Casapalca the plant known as *Metalurgia Moderna*. At first there was but one five-stamp mill, and the auxiliary appliances consisted in Blake mills, Hartz jigs, Frue vanners and revolving tables. The plant was very successful, and was enabled to utilize large quantities of abandoned ore. Later, in 1894, the writer designed and installed a plant at Aguas Calientes. After this a great many others followed, in which several modern improvements were introduced. They were originally intended for the treatment of silver ores, usually associated with galena, chalcopryite, and especially blende. As nearly all silver ores contain gold in the form of sulphides and tellurides, many of the silver mine companies have appliances for gold concentration, the concentrates being either exported or treated by cyaniding.

The smelting works of Casapalca were probably the first to use crude oil in ordinary reverberatory furnaces. Later they undertook the smelting of lead ores, and still later copper ores. The reverberatory furnaces were first replaced with Brown roasters, and more recently by agglomerating pots. To-day the plant carries its work to the casting of copper bars, containing some gold and silver, for exportation.

The largest and most important smelter in South America is the Tinyahuarco smelter, also in Cerro de Pasco. It was started in 1900 and has all modern appliances, including coke apparatus, MacDougal roasters, water jackets, Smith converters, and all the necessary auxiliaries. Power is obtained from enormous hydro-electric plants, from which is also derived the power required in all mining operations. The plant works copper ore of as low a grade as 5 per cent, the finished product being in the form of bars.

Cyaniding has been tried with both gold and silver ores, but on the whole with little success. At present it is planned to install a cyaniding plant in Patatz for the treatment of auriferous pyrites. Careful tests show that about 95 per cent of the gold can be extracted from this ore.

Bismuth in bars is now produced in one of the Cerro de Pasco plants.

The paper gives a long list of all the metallurgical plants in Peru, including those for handling and preparing the ore, smelters, and amalgamation, leaching and cyaniding plants. It closes with a description of the metallurgical laboratory of the Engineering School of Lima.

Progress in Glass Making

Program of Next Meeting of New York Section of Society of Chemical Industry

The next meeting of the Society of Chemical Industry, New York Section, will be held on Friday evening, March 24, at the Chemists Club. The subject for the evening will be "Glass," and the following papers will be presented:

"Development of Low Expansion Glass," by Dr. E. C. SULLIVAN of the Corning Glass Works, Corning, N. Y.

"American Pressed and Blown Glass and the Table Ware Industry," by S. R. SCHOLES of the Mellon Institute, Pittsburgh, Pa.

"Glass We See Through," by G. OSGOOD ANDREWS, special representative of the Plate Glass Manufacturers of America.

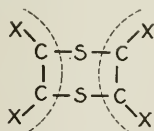
The Reclaiming of Rubber Waste

BY ANDREW H. KING

"Old rags, rubbers, and old gum boots" has been the cry of the rag man for generations. It is by such men that modern efficiency reaches into every nook and corner of the country for worn out rubber goods. Such material has a value, not only to those interested in its recovery, but to society as well, since the reclaimed product or shoddy replaces new rubber either wholly or in part in thousands of instances, thus leaving a larger portion of the supply for the production of high grade articles, such as tires. Were it not for the shoddy industry, the supply would be considerably short of the demand, and the resulting prices would place rubber articles beyond the reach of many people. In fact, the rubber tired automobile would be a luxury rather than the necessity that it has come to be. I do not wish to give the impression that shoddy, as it is now made, is anyway nearly as good as new rubber. It has a much lower tensile strength, elasticity, and wearing power, but its properties are sufficient to fit it for many uses to which it is applied.

In my previous articles in the issues of January 1 and 15 of this journal I endeavored to show how rubber is reinforced with cotton for the production of many useful things. The first concern of the shoddy manufacturer is the removal of this fabric. This is accomplished by the use of various reagents which convert the cellulose to water soluble forms. The next step is to make the rubber, which here consists of caoutchouc and fillers, soft and plastic. It must be capable of mixing with more fillers, such as sulphur, litharge, etc., and of further vulcanization. A true reclaiming process would return the rubber in its original state, but so far this has been impossible.

Vulcanization, as has been stated, consists primarily of the union of sulphur with the rubber hydrocarbon. The degree of vulcanization is dependent upon: first, the quantity of sulphur present; second, the time and degree of heat used; and third, upon the presence of various accelerators. Like all chemical reactions, mass action plays a considerable part in determining how much sulphur shall unite with the rubber. There is always some free sulphur; that is, sulphur extractable by solvents such as acetone. That which cannot be extracted we call combined sulphur. Weber considers that the true vulcanizing effect consists not only in the formation of an addition product, but also a conjugation of india rubber molecules as well. He illustrates thus:



Vulcanization always takes place in steps. Axelrod claims that it consists of two distinct processes: first, the action of heat on rubber, which tends to depolymerize it; and second, the entry of sulphur into the rubber molecule. Since the removal of the combined sulphur is as yet impossible, the rubber chemist has done the next best thing, which is to depolymerize the waste according to Axelrod's idea.

Every process, with but few exceptions, consists of two steps; first, the destruction of the fabric by hydrolysis; and second, the depolymerization of the rubber.

In order to give an idea of the relative value of different grades of rubber scrap, the New York prices

for Dec. 30, 1915, are quoted below. These prices are for carload lots delivered:

Boots and shoes.....	10½ c. lb.
Trimmed arctics.....	8½ c. lb.
White tires, Goodyear.....	7½ c. lb.
Auto tires, standard white.....	5½ c. lb.
Auto tires, standard mixed.....	5½ c. lb.
Auto tires, stripped unguaranteed.....	3½ c. lb.
Auto peelings, No. 1.....	9 c. lb.
Auto peelings, No. 2.....	7½ c. lb.
Inner tubes, No. 1.....	27 c. lb.
Inner tubes, No. 2.....	12½ c. lb.
Inner tubes, red.....	12½ c. lb.
Irony tires.....	2 c. lb.
Bicycle tires.....	3½ c. lb.
Solid tires.....	1½ c. lb.
White scrap, No. 1.....	11½ c. lb.
White scrap, No. 2.....	9½ c. lb.
Red scrap, No. 1.....	5½ c. lb.
Red scrap, No. 2.....	7½ c. lb.
Mixed black scrap, No. 1.....	3½ c. lb.
Mixed black scrap, No. 2.....	3 c. lb.
Rubber car springs.....	3½ c. lb.
Horse shoe pads.....	3½ c. lb.
Mattings and packings.....	1 c. lb.
Garden hose.....	1½ c. lb.
Air brake hose.....	5½ c. lb.
Cotton fire hose.....	2½ c. lb.
Large hose.....	1½ c. lb.
Hard rubber scrap, No. 1, bright fracture.....	23 c. lb.
Battery jars, red.....	2½ c. lb.
Insulated wire stripping.....	2½ c. lb.
Rubber heels.....	3½ c. lb.

Scrap may be classified as follows:

I. Fabric free.—This class includes all grades of scrap which consist of pure compounded rubber, that is, rubber compound containing no cotton, wire, iron studs, etc. Under this head comes inner tubes, auto tire peelings, druggists' sundries, etc.

II. Fabric bearing.—This class includes those grades of scrap containing fabric, wire, etc. Hose of all kinds, boots and shoes, stripped tires, etc., are included in this class.

III. Ebonite.—Under this head comes all hard and semi-hard scrap, such as hard valves, sundries, etc.

As would be expected, the treatment differs for each class.

FABRIC FREE

This is, without doubt, the easiest class to reclaim. In fact, there are numerous instances where such material is added directly to rubber mixings. Reclaiming consists simply of softening and depolymerizing the scrap. The finely ground material is mixed with vaseline, tar, carboic acid, or heavy mineral oil either alone or mixed with rosin. This mixture is heated in live steam at 300 to 375 deg. Fahr. for from six to forty-eight hours, depending upon the class of material being treated.

FABRIC BEARING

By far the largest portion of rubber scrap comes under this class. Such material on arrival at the shoddy plant is sorted. All metal parts are removed. Where profitable, the outer layer of rubber is cut off. Thus auto tire treads and often the sides are skived (cut away) and placed in class I under auto tire peelings. Auto tire beads are also removed and placed in class III.

Following sorting, all material is ground finely by means of rapidly rotating knives. It is next screened and passed under the magnetic separator. This consists usually of a series of electro-magnets having a small belt passing across the pole face at right angles to the belt conveyor which carries the ground scrap. Any particles of iron or steel are drawn up and thrown to one side.

The separation of the fabric from the rubber compound is accomplished by various processes, which will be discussed under the following heads:

- I. Mechanical.
- II. Acid.
- III. Alkali.
- IV. Solution.

Mechanical Process.—This method is now little used. It consisted of blowing out the fluff by means of a regulated blast of air. It was a forerunner of modern air separation or grading. In this instance it proved a failure, since the fluff was never entirely free from rubber and vice versa. Consequently the separation was very incomplete.

Acid Process.—The first attempts at chemical separation were made along this line. The original process consists of heating the ground scrap with dilute sulphuric acid in steam jacketed kettles. An acid concentration of 3 to 5 per cent is used. The run lasts from 10 to 24 hr. at 320 to 340 deg. Fahr., depending upon the kind of scrap. Stirring devices are customary.

A clever modification of this process is that of W. A. Kōneman, U. S. Pat. 823,053, Oct. 9, 1905. He uses hydrochloric or sulphuric acid, 5 to 10 per cent, and common salt in amount one-third of the weight of fiber and sulphur of the stock under treatment. He boils the mixture in an open vat by means of steam coils one hour at 220 deg. Fahr. without stirring. This process yields a very good product since the nerve of the rubber is not greatly attacked, due to the short time and low temperature of exposure to the acid. This has a decided advantage over the use of sulphuric acid alone, which tends to char the rubber hydrocarbon.

Another ingenious modification of the acid process consists in the substitution of zinc or magnesium chlorides for the sulphuric acid. Terry, English Pat. 11,482 (1911). Either of these supplies sufficient acid by hydrolysis.

Those processes using free acid besides hydrolyzing the cellulose to the water soluble form, also effect the removal to a more or less extent of the basic mineral fillers such as zinc oxide, lime, magnesia, etc. Sulphur in neither the free nor the combined state is in the least affected.

Following the acid treatment, the product must be well washed. The contents of the vat are usually worked over a riffler which is customarily about 300 ft. long and 2 to 6 ft. wide, the sides being a foot in height. This long chute is inclined, and has slats 2 to 4 in. in height spaced a foot apart. By means of a stream of water the vat liquor is washed away, and the rubber worked down the incline. At the bottom it goes into a settling box, where the floating stock is skimmed off. From here, the water used passes through a screen and into the sewer.

The wet stock is shoveled out of the settling box and further washed by passing it through corrugated washing rolls, just the same as in washing raw rubber. It is then taken to a centrifuge where most of the water is whirled out. It is further dried by exposing it in trays in a drying room.

The use of the riffler has been condemned by various rubber engineers as inefficient and wasteful. In fact, an adaptation of metallurgical washing methods to the problem would seem to me as beneficial.

The washing operation is of great importance in all shoddy processes, whether acid or alkali. Moreover, it is very difficult to remove the last trace of reagent, due to absorption by the rubber colloid. In acid processes this is not so dangerous, since washing will easily bring the acid content down to less than $\frac{1}{2}$ of 1 per cent. By the addition of zinc oxide or other basic material to the finished product it may be neutralized. Unless this is done, the shoddy is liable to vary in rate of vulcanization, and in the case of incomplete washing it is liable, when 3 per cent acid is present, to be porous. In alkali processes absorption causes considerable trouble, since a small quantity of

alkali, less than $\frac{1}{2}$ of 1 per cent, acts as an unregulated accelerator, and the product is quite likely to harden on ageing. The presence of more than $\frac{1}{2}$ per cent alkali retards vulcanization, and if 5 per cent is present it is impossible to cure the product within reasonable time.

The remedy is obviously some acid treatment using an acid which has no harmful effects on rubber. L. T. Petersen, U. S. Pat. 774,727, June 24, 1904, produces first an alkali shoddy and then heats it with carbolic acid. This gives an excellent solution of the problem since inactive sodium phenolate is formed and the excess carbolic acid acts as an antiseptic.

The shoddy at this stage—in the pans of the dry room—has but little cohesiveness. It is crumbly, and must be depolymerized before it is fit for use. This is accomplished just as in treating fabric free material. However, tar is the chief material added. Varying percentages are mixed with the crumb, and the whole heated in contact with steam at around 300 deg. Fahr. for several hours, depending upon the kind of scrap being treated.

This heating, while quite necessary, has its disadvantages. As stated before, acid shoddy contains free sulphur, consequently long heating serves to further vulcanize the product, thus decreasing its value.

Alkali Processes.—Most of the shoddy manufactured in this country is made by the use of alkali. The first patent was granted to A. H. Marks, U. S. Pat. 635,141, Oct. 17, 1899. All other alkali patents are modifications of it. Marks accomplishes the removal of the fabric and depolymerization of the rubber at one heating. His process consists in submerging the finely ground rubber waste in a dilute alkaline (3 per cent sodium hydroxide recommended) solution in a sealed steam jacketed vessel, the contents of which are heated with stirring to a temperature of 344 deg. Fahr. (125 lb. of steam), which is maintained for twenty-four hours, more or less, as is necessary.

This is the gist of the most important patent in American shoddy practice, and is decidedly an advantage over the acid process. The finely ground waste is submerged in an inner vessel in 3 per cent alkali solution. This is sealed and steam at 125 lb. is turned into the container. The heat is continued with stirring as long as experience dictates, twenty to twenty-four hours is usual.

A modification of Marks' process is that by R. B. Price, U. S. Pat. 762,843, May 26, 1904. He treats finely ground waste with sodium hydroxide solution, boiling above the melting point of sulphur (232 deg. Fahr.). His solution may contain as much as 66 per cent NaOH. He claims that 1 lb. water and 1 to 2 lb. alkali per pound of rubber is about right. He boils the mixture at atmospheric pressure at 350 deg. Fahr., using a reflux condenser. In a previous patent, U. S. Pat. 693,151, April 11, 1901, he recommends the use of superheated steam (300 deg. Fahr. to 450 deg. Fahr.) for depolymerizing. A bath of 5 to 25 per cent sodium thiosulphate is given for the removal of free sulphur.

Probably a better modification of the Marks process is that of L. T. Petersen, U. S. Pat. 774,727, June 24, 1904. The finely ground scrap is treated in a heater differing but little from that of Marks, with a 10 to 15 per cent solution of alkali. This heat lasts but three hours, after which the stock is separated from the liquor which is likely used over again. It is washed and centrifuged, and then placed in a heater with a 1 to 10 per cent solution of phenol or similar hydrocarbon, such as cresol. The solution must be

weak enough to not dissolve any rubber. The heater for this step is similar to the one used for the alkali treatment. The steam pressure may be varied in the jacket from 50 to 175 lb. This heat lasts from six to forty-eight hours.

An electrolytic modification of the alkali process is that of C. S. Heller, U. S. Pat. 1,024,937, June 22, 1911. As an example of his process he cites a solution of 30 lb. alkali in 600 lb. water. To this are added 100 lb. of rubber waste and $\frac{1}{2}$ lb. of ferric hydroxide. This solution is electrolyzed at a voltage of 0.4 to 0.6 volts and 700 to 1000 amperes. The temperature recommended is 360 deg. Fahr. The current is reversed twelve times per day. He claims to remove the sulphur.

Washing and drying are carried out much the same as in the acid process. Marks washes his product on a riffler and then through washing rolls. It is then fed wet through a hot mixing mill where it is dried and finally sheeted on the same set of rolls. These sheets are stored, ready for use or shipment. Depolymerized acid shoddy is also dried on hot rolls.

The advantages of the Marks process consist in removing, first, the free sulphur which unites with the alkali, forming sodium polysulphides; and second, all saponifiable material, such as rubber substitute, vegetable oils, etc. The process is very good, and the only objection is the slight trace of free alkali which cannot be removed. This defect is corrected by Petersen's patent, as before mentioned.

Below are some typical figures which will indicate the properties of the most important shoddies, namely, those from auto tires, boots and shoes, air brake and bicycle tires. These are alkali shoddies made by the Marks process. The physical tests were made on a vulcanized compound prepared as follows: 93 per cent shoddy, 4 per cent sulphur and 3 per cent lime. For sake of comparison, tests on Highlands Fine Para and Plantation Smoked Sheets are given. These compounds contained 90 per cent rubber, 1 per cent lime and 9 per cent sulphur.

	Grade Shoddy	Rubber	Ash	Acetone Extract	Chloroform Extract	Total Sulphur, Per Cent	Specific Gravity	Tensile Strength, Lb. Sq. In.	Ultimate Elongation, Per Cent
Auto tire	56.54	40.00	9.48	14.13	3.46	1.40	815	450	
Boots & shoes	46.35	50.15	8.25	17.55	3.50	1.60	800	210	
Air brake	50.00	45.29	16.26	12.48	4.12	1.51	810	400	
Bicycle tire	44.04	52.00	10.14	12.15	3.96	1.67	845	250	
H. F. Para	90.00		*2.12		9.00		2,150	900	
Smoked sheets	90.00		*3.33		9.00		1,970	950	

*On the raw rubber.

Solution Methods.—Various solution methods have been proposed from time to time. The patent of P. Alexander, U. S. Pat. 821,394, Aug. 10, 1905, is the only one deserving serious attention. This process consists in the production of a colloidal emulsion of rubber in water. Any fabric or mineral fillers can be removed by filtration. He cites as an example of his process the following: 1000 Kg. of scrap are heated to 150 deg. C. with 3000 Kg. benzole for three to four hours in a closed vessel under pressure. Undissolved material is then mechanically removed. The solution is returned to the pressure vessel and heated to 150 deg. C. for about three hours with 200 Kg. sodium hydrate in 350 Kg. water. The solution is then steam distilled at low temperature to remove the benzole. The aqueous emulsion is filtered to remove mineral fillers. The rubber is precipitated by means of acid or combustion gases.

It is said that the process is inoperative. At least, there are some fundamental objections to its use. Experience with other rubber solvents has demonstrated that the combined sulphur would not be removed. Also, rubber precipitated from solution shows a marked diminution in tensile strength as compared with the original previous to solution.

Ebonite Waste.—Under this head comes all sorts of hard and semi-hard waste. The material when finely ground is termed dust and is so used in mixing.

A very ingenious method for the recovery of such waste is the patent of Thomas Gare, U. S. Pat. 967,751, Aug. 27, 1906. He subjects ground scrap to great pressure, one-half ton to the square inch, in a mold heated from 350 deg. Fahr. to 450 deg. Fahr. The combination of high temperature and pressure tends to soften and coalesce the dust so that molded articles closely resembling new goods are produced.

Attempts to Remove the Combined Sulphur.—Numerous patents have been granted for the removal of sulphur. The following is a list of the more important:

Inventor	Reagent	Patent	Date Granted
Theilgaard	Sodium sulphite	Eng. Pat. 10,821	1899
Dewer	Lime	Eng. Pat. 4,803	1901
Theilgaard	Sodium sulphide	Eng. Pat. 8,041	1899
Theilgaard	Cyanides	Eng. Pat. 10,822	1899
Bary	Metallic oxides	Eng. Pat. 7,153	1910

Bary and Weidert state that it is possible to remove the combined sulphur, and Hinrichsen and Kindscher, who examined the action of alcoholic soda and finely divided metals on both hot and cold vulcanized rubber came to the same conclusion.

Alexander differs with these men and claims that the sulphur they removed was only some residual free sulphur. This is extremely hard to extract, due to absorption. Prolonged treatment with hot acetone under pressure is necessary, and then it is a question if all the absorbed sulphur is removed.

To date it seems quite probable that the removal of the combined sulphur is likely to prove impossible. The difficulties are very great. Rubber is such a complex substance, and its affinity for sulphur is so strong that any reagent powerful enough to remove the combined sulphur would likely make the rubber unfit for commercial use.

It is the aim of modern civilization to prevent waste in whatever form it may occur. In rubber this prevention is only partially successful. It has been the aim of the writer to set forth the various important attempts so that the experimenter to come will not cover ground which has been gone over in the past. It is hoped that this paper will convey an impression of the difficulties in the way of a true solution of the problem, and also give us due respect for the service to society of those men who go through our streets calling "Old rags, rubber and old gum boots."

Franklin Institute Lectures

The following lectures are scheduled to be given before the Franklin Institute in Philadelphia during the next few weeks.

March 23—"Recent Developments in Electrical Apparatus," by Harold Pender.

March 30—"Some Problems in Physical Metallurgy at the Bureau of Standards," by George K. Burgess.

April 6—"Use of Powdered Coal in Metallurgical Processes," by C. J. Gadd.

April 13—"Heat Measurement as Related to the Industries," by Charles W. Waidner.

April 19—"Scientific Research in Relation to the Industries," by Charles P. Steinmetz.

Refrigeration in France*

BY L. MARCHIS

(Concluded from page 191)

III—Refrigerating Machines

1. CAPACITY AND PERFORMANCE

Mr. Marchis proposes the following definitions relating to the capacity and performance of refrigerating machines.

(a) *Interior Régime*. It is first necessary to consider, in the operation of refrigerating machines, the *interior régime* and the *exterior régime*.

The *interior régime* depends not only on the nature of the refrigerating fluid in use, but also on all the transformations of this fluid in the interior of the machine. It is difficult, not to say impossible, to define in any exact manner the various stages of these transformations. And for this reason, by analogy with the case of an ideal engine operating according to the Carnot cycle, we are led to characterize the internal régime of a compressor by means of the three following temperatures.

1. Temperature of vaporization of the refrigerating agent, corresponding to the pressure measured on the inlet gage.

T_v = Temperature, absolute.

t_v = Temperature, Centigrade.

$T_v = t_v + 273$.

2. Temperature of condensation of the refrigerating fluid, corresponding to the pressure measured at the exhaust gage.

T_c = Temperature, absolute.

t_c = Temperature, Centigrade.

$T_c = t_c + 273$.

When the refrigerating fluid operates at temperatures above the critical temperature, the serpentine of the liquefier plays the rôle of a cooler of the gas. For the latter, one can only define an average temperature, somewhat vaguely known. If by means of thermometers plunged into the gas, measures are taken, $t_c^{(1)}$ and $t_c^{(2)}$, of this gas at admission and discharge from the serpentine of the liquefier, we may take as the average temperature of the gas in the serpentine the mean value

$$t_o = \frac{t_c^{(1)} + t_c^{(2)}}{2}$$

3. Temperature of the refrigerating fluid on its arrival at the regulating valve, temperature measured by means of a thermometer plunged in the fluid.

T_r = Temperature, absolute.

t_r = Temperature, Centigrade.

$T_r = t_r + 273$.

This temperature is the lower, the better, the cooler for the liquid.

The difference between the two temperatures, $T_r - T_v$, characterizes the effect of the regulating valve.

4. Industrial experience shows that the values of the temperatures t_r , t_c , t_v , most commonly observed are the following:

$t_v = -10$ deg. C., $T_v = 263$ deg. absolute.

$t_c = +25$ deg. C., $T_c = 298$ deg. absolute.

$t_r = +15$ deg. C., $T_r = 288$ deg. absolute.

We propose to take these temperatures as suited to define the normal internal régime.

(b) *External Régime*. The study of the internal régime of the machine involves that of the transformations of the refrigerating fluid. That of the external régime concerns the interchanges of heat between the refrigerating fluid and the mobile media, that to be

cooled about the evaporator, and that for cooling about the liquefier. The external régime is of more especial interest in the refrigerating industry. It permits, in effect, the standardization of the refrigerating action of the machine (useful effect) and of determining the expense of circulating water in the liquefier. The external régime may be characterized by the following temperatures:

1. Average temperature of the substance to be cooled in contact with the evaporator.

θ_v = temperature, Centigrade, corresponding to t_v .

If $\theta_v^{(1)}$ and $\theta_v^{(2)}$ are the temperatures of the substance to be cooled, before and after contact with the evaporator, we may take

$$\theta_v = \frac{\theta_v^{(1)} + \theta_v^{(2)}}{2}$$

2. Temperature of the condensing water at admission to the liquefier (whether or not the liquefier is provided with a cooler for the liquid).

θ_{ce} = temperature, Centigrade.

3. Temperature of the condensing water as it issues from the liquefier

θ_{cs} = temperature, Centigrade.

4. We propose to adopt, for the normal conditions of operation for the external régime, the following values of the temperatures:

For the cooling of brine:

$\theta_v = -5$ deg. C.

$\theta_v - t_v = 5$ deg. C.

In case of direct expansion

$\theta_v = 0$ deg. C.

$\theta_v - t_v = 10$ deg. C.

$\theta_{ce} = +12$ deg. C.

$\theta_{cs} = +20$ deg. C.

$$\frac{\theta_{ce} + \theta_{cs}}{2} = 16$$

$$t_c - \frac{\theta_{ce} + \theta_{cs}}{2} = 9$$

$$\frac{t_c + t_r - \theta_{ce} + \theta_{cs}}{2} = 4$$

(c) *Certain Definitions and Notations Relating to the Calculation of Compressors.*

1. Units of refrigeration produced in the evaporator per stroke of the piston = Q_v .

$$Q_v = Mr(T_v)$$

M = mass of refrigerating fluid circulating in the machine per stroke of the piston.

$r(T_v)$ = heat of vaporization of the refrigerating fluid at the temperature T_v .

$V = M\mathcal{V}(T_v)$ = volume swept by piston.

$\mathcal{V}(T_v)$ = specific volume of the saturated vapor of the refrigerating fluid at the temperature T_v .

We propose to give the name *Theoretical specific volumetric production* to the expression

$$P_{sv}^{(1)} = \frac{r(T_v)}{s(T_v)} \left(\frac{\text{units of refrigeration-kilograms}}{\text{met}^3} \right)$$

2. Theoretical indicated work per stroke of piston,

$$W_i = \frac{m}{m-1} P_v V \left[\left(\frac{P_c}{P_v} \right)^{\frac{m-1}{m}} - 1 \right]$$

where

P_c = pressure at the liquefier indicated by the corresponding gage.

P_v = pressure at the evaporator corresponding to the temperature T_v .

If the pressures are expressed in kilograms per square meter and the volumes in cubic meters, the work W_i is expressed in kg.-meters (if in pounds per square foot and cubic feet, work is expressed in foot-pounds).

*A paper read before the International Engineering Congress in San Francisco.

If the pressures are expressed in Newtons per square meter and the volumes in cubic meters the work W , is expressed in Joules.

We propose to give the name *theoretical specific economic production* to the expression

$$P_{se}^{(t)} = \frac{P_{sv}^{(t)}}{\frac{W_i}{v}} \left(\frac{\text{units of refrigeration-kilogram}}{\text{kg.-meter or Joule}} \right)$$

If the work W_i is expressed in Joules and if $K_{wh}^{(t)}$ is the corresponding number of watt-hours, we have

$$K_{wh}^{(t)} = \frac{W_i}{36 \times 10^6}$$

$$P_{se}^{(t)} = \frac{1}{36 \times 10^6} \times \frac{P_{sv}^{(t)}}{K_{wh}^{(t)}}$$

Let us place

$$\Pi_{se}^{(t)} = 36 \times 10^6 P_{se}^{(t)}$$

We then have

$$\Pi_{se}^{(t)} = \frac{P_{sv}^{(t)}}{\frac{K_{wh}^{(t)}}{V}} \left(\frac{\text{units of refrigeration-kilogram}}{\text{kilowatt-hour}} \right)$$

The factor m which enters into the expression for W_i is not well known. The values commonly assumed are as follows:

NH ₃	$m = 1.32$
SO ₂	$m = 1.27$
CO ₂	$m = 1.30$

3. We propose to give the name *indicated thermal performance* to the abstract number

$$\varphi_i = EP_{se}^{(t)} = 36 \times 10^6 \times \Pi_{se}$$

E being the mechanical equivalent of heat.

Where the unit of work is the Joule and the unit of mass is the kilogram, $E = 9.8 \times 425$.

4. The theoretical refrigerating power of a compressor per unit of volume swept by the piston or the *theoretical volumetric refrigerating power* may be represented by the notation

$$P_{rv}^{(t)} \left(\frac{\text{units of refrigeration-hour}}{\text{cubic meter}} \right)$$

If n is the number of revolutions per minute we have

For a single-acting machine: $P_{rv}^{(t)} = 60 \times n \times P_{sv}^{(t)}$
For a double-acting machine: $P_{rv}^{(t)} = 120 \times n \times P_{sv}^{(t)}$

5. The theoretical cooling power of the condenser per unit of volume swept by the piston, or *theoretical volumetric cooling power* may be represented by the notation

$$R_{cv}^{(t)} \frac{\text{kilogram calories}}{\text{cubic meter}}$$

In virtue of the principle of equivalence, it has for expression

$$R_{cv}^{(t)} = P_{sv}^{(t)} \left(1 + \frac{1}{E} \times \frac{I}{P_{se}^{(t)}} \right)$$

6. The theoretical consumption of water at the condenser per unit volume swept by the piston or *theoretical volumetric consumption of water* is

$$\Delta_{cv}^{(t)} = \frac{\text{kilogram}}{\text{cubic meter}}$$

It has for value the expression

$$\Delta_{cv}^{(t)} = \frac{R_{cv}^{(t)}}{\theta_{cs} - \theta_{ce}}$$

The theoretical calculation of a compressor is then based on the knowledge of $P_{sv}^{(t)}$ and of $P_{se}^{(t)}$

(d) *Certain Definitions and Notations Relative to Compressors in Industrial Operation.*

1. We propose to give the name *practical specific volumetric production* to the quotient:

$$\frac{\text{kilogram frigories}}{\text{cubic meter}} P_{sv}^{(p)} = \frac{\text{Units of refrigeration produced in the evaporator by the vaporization of the refrigerating fluid.}}{\text{Volume in cubic meters actually swept by the piston.}}$$

If, as is usually done, we measure the units of refrigeration produced in the evaporator by the cooling of the external medium, this method assumes that the *efficiency of the evaporator* (ratio of the units of refrigeration actually produced in the evaporator to the units measured by determining the cooling of the external medium) is very near unity; that is, that the evaporator is well filled with refrigerating fluid.

If this method of procedure is not followed, it is necessary to measure the mass of fluid circulating in the machine during a determined time, and this is very difficult to realize to a sufficiently accurate degree.

The *practical volumetric refrigerating power*,

$$P_{rv}^{(p)} \frac{\text{units of refrigeration-hour}}{\text{cubic meter}}$$

has for value the expression:

For a single-acting machine

$$P_{rv}^{(p)} = 60 \times n \times P_{sv}^{(p)}$$

For a double-acting machine

$$P_{rv}^{(p)} = 120 \times n \times P_{sv}^{(p)}$$

These expressions assume that $P_{sv}^{(p)}$ corresponds to one stroke of the piston.

2. We propose to give the name *volumetric efficiency* of a compressor to the ratio

$$\varphi_v = \frac{P_{sv}^{(p)}}{P_{sv}^{(t)}}$$

As the number of units of refrigeration really produced in the evaporator has for value the expression $Mr(T_v)$, this efficiency is also equal to the ratio of the actual to the theoretical volume of the compressor.

3. We propose to give the name *practical specific economic production* (related to the indicated kilowatt-hours) to the ratio

Units of refrigeration produced in the evaporator by the vaporization of the refrigerating fluid.

$$\Pi_{se}^{(p)} = \frac{\text{Number of indicated kilowatt-hours furnished to the compressor.}}{\text{Number of indicated kilowatt-hours furnished to the compressor.}}$$

This definition must be completed by an indication of the mechanical efficiency of the compressor, ϵ_m or ratio of the number of kilowatt-hours actually delivered on the compressor shaft to the number furnished to it.

The *practical specific economic production* (related to the kilowatt-hours expended on the compressor shaft) has for value the expression:

$$\Pi_{se}^{(p)} \times \epsilon_m$$

4. We propose to give the name *economic efficiency* of the compressor to the ratio:

$$\varphi_e = \frac{\Pi_{se}^{(p)}}{\Pi_{se}^{(t)}}$$

This number measures also the ratio of the indicated kilowatt-hours actually furnished to the compressor to the theoretical indicated kilowatt-hours.

5. The *practical volumetric refrigerating power* of the liquefier is

$$R_{cv}^{(p)} = P_{sv}^{(p)} \left(1 + \frac{36 \times 10^6}{E} \times \frac{1}{\Pi_{se}^{(p)}} \right)$$

When $E = 9.8 \times 425$

$$R_{cv}^{(p)} = P_{sv}^{(p)} \left(1 + 863.3 \frac{1}{\Pi_{se}^{(p)}} \right)$$

6. The practical volumetric consumption of water is

$$\Delta_{cv}^{(p)} = \frac{R_{cv}^{(p)}}{q_{cs} - q_{cc}}$$

(e) *The Construction of Refrigeration Machines in France.*

As is shown by the statistical table annexed hereto, the refrigerating capacity of the machines in operation in France attains, for fixed installations, at least 74,000,000 frigories per hour (units of refrigeration). A great number of these machines are built in France—at least 60 per cent of the preceding capacity.

If we consider the nature of the refrigerating fluid, the machines built in France fall into five types:

- (1) Ammonia.
- (2) Sulphur dioxide.
- (3) Carbon dioxide.
- (4) Methyl chloride.
- (5) Water under partial vacuum.

The first four classes of machine are of the so-called *compression* type. Machines of the absorption type are no longer built in France. There are only a few now in operation in ice plants.

Methyl chloride is only used in the Douane machines; this medium is moreover not employed in other countries.

Furthermore, the type using water under partial vacuum is peculiar to the Westinghouse Company, which builds it under the direction of its inventor, Mr. Maurice Leblanc. We shall refer to this machine at a later point. The ammonia machine is built especially by:

- (1) The Société des Moteurs à Gaz et d'Industrie Mécanique (formerly Fixary).
- (2) The Société Delaunay-Belleville.

The compressors of the first company are developed from the Linde type. They realize the greatest refrigerating capacities at present obtained. Thus, for example, this company has now under construction, for use in connection with the driving of mine shafts, compressors for 330,000 units of refrigeration (165,000 units per cylinder) formed of two cylinders opposed and mounted on the same foundation.

The Delaunay-Belleville Company builds compressors with flat bed-plate and with valves placed at the sides (axes of valves normal to axis of cylinders).

These compressors, double-acting, operate at rotative speeds not exceeding 150 r.p.m.

Recently a single-acting compressor under the name "equator" has been proposed, with a rotative speed of 500 r.p.m. At a certain point in the stroke the piston uncovers certain openings by which enter the gases coming from the evaporator. As to the exhaust valves, they are formed of simple bars of steel placed over the openings connecting with the condenser. This compressor, still under test, has given good results.

Machines operating with sulphur dioxide are more numerous than those with ammonia, but their total refrigerating capacity is less than that of the ammonia machines.

The Pictet Company is one of the oldest houses building machines operating with sulphur dioxide. The present type shows a cylinder with jacket for water circulation and a double stuffing-box for the circulation of water, which assures the cooling of the piston rod. In order to realize high rotative speeds (up to 300 r.p.m.), use is made of valves formed of a light disk held at the center.

The house Lepou also builds machines operating with sulphur dioxide, with very light disk valves for high rotative speeds.

A type of compressor altogether peculiar to France is the Audiffren-Singrün. It has neither stuffing-box nor valves. The compressor is imprisoned in a hermetically

sealed inclosure, on the interior of which acts the pressure of the liquefier. The compressor may be operated by an external motor without piercing the wall of the space which contains it, that is to say, without employing a stuffing-box. To this end it is sufficient to revolve the closed compartment containing the compressor. The mechanism of the latter, to which is given an alternating movement, is maintained fixed in space by means of a mass of lead of sufficient weight, which ballasts the shell containing the pump of the compressor. This machine is especially used for the manufacture of ice in small quantities for domestic use, yielding 3 to 4 kg. (6.6 to 8.8 lb.) per hour. For such purpose it is furthermore very practical, for it requires no supervision and can be put into operation by any domestic. However, larger machines are now in hand, capable of making 50 and 100 kg. (110 and 220 lb.) of ice per hour. We shall refer at a later point to a traveling installation in which this type of compressor has yielded the best of results.

The house Dyle and Bacalan builds compressors operating with carbon dioxide, of the English type "Hall." This house has more particularly specialized in the construction of machines for small dairies and for marine uses.

The Froid Industrial Company also builds machines using carbon dioxide for marine service.

Mr. Maurice Leblanc of the Westinghouse Company, has brought into service a machine in which water is used as the refrigerating fluid. It produces the cooling of brine by inducing its evaporation under a suitable reduction of pressure. This partial vacuum is realized by means of a jet of vapor, which, issuing at high speed from an orifice surrounded by a suitable diffuser, entrains large quantities of water vapor.

However, in order to obtain in the evaporator a temperature of the brine sufficiently low, that is a sufficiently low tension of the vapor emitted by the solution, it is necessary to realize at the condenser of the vapor a very low pressure. This is realized by the use of an *ejector-condenser*, that is, a condenser in which the vacuum pump is constituted by a liquid ejector.

This machine presents the advantage of having neither poppet valves nor check valves subject to rapid wear. It is also very silent.

An important saving is realized by the use in the vapor ejectors of exhaust vapor from other vapor motors, as turbines for example. Thus at the refrigerating abattoir at Chasseneuil (Poitou), the exhaust from a steam turbine under a pressure of 2 kg. per sq. cm. (28.4 lb. per sq. in.) passes into the ejectors and produces in the evaporator a vacuum of 2 mm. (0.08 in.) of mercury.

The efficiency of an ejector machine is the ratio of the number of units of refrigeration produced in the evaporator to the number of heat units absorbed by the refrigerating water in the condenser. If consideration is given to the temperatures corresponding to the tensions of the vapor of water in the evaporator and the condenser, the efficiency diminishes rapidly when the difference of these temperatures increases. It has a value about 30 per cent for a difference of temperature equal to 15 deg. or 20 deg. C., that is, a temperature of 5 deg. to 0 deg. C. in the evaporator for a temperature of +20 deg. C. in the condenser.

For this reason, the ejector machine is well suited to use in all cases where it is not necessary to push the refrigerating effect below 0 deg. C. Such is the case in chemical and pharmaceutical industries. The largest installation of this type has a machine of 1,050,000 frigories per hour (units of refrigeration) with a temperature of the brine on entering the evaporator = +26 deg. C. and on leaving the evaporator = +19 deg. C.

This machine was installed at the plant of M. Gillet at Lyon-Serin for cooling bichloride of tin, used in the process of dyeing black silk.

But it is on shipboard that ejector machines may find their most significant field of use. They employ a refrigerating fluid which involves no danger of fire and which can be renewed with sea water. Likewise, ejector machines serving to cool to a few degrees below 0 deg. C the air circulating in ammunition rooms have been installed on a large number of French battleships, and even on Russian and Austrian ships of the same type. Machines of this type have also been employed for the refrigeration of food stores for passengers on four steamers of the French merchant marine. The total number of machines installed on shipboard is fifty-eight, with an aggregate refrigerating capacity of 2,000,000 frigories-hours (units of refrigeration).

The ejector machine presents the serious drawback of requiring at the condenser a considerable amount of cooling water.

On this account, for stationary installations, Mr. Leblanc has undertaken the construction of a pump mechanically operated, and capable, with a small volume, of aspirating the enormous volumes of water vapor required by the use of this substance as the refrigerating fluid. To this end he has turned to the rotative type of pump.

But the problem presents serious difficulties. The rotary compressor must be of small dimensions, it must require only a small power for operation and must, nevertheless, be capable of aspirating several cubic meters per second of a vapor of density much less than that of air. But, the less the density of the aspirated air, the greater must be the peripheral velocity of the vanes; the more the power absorbed by the compressor is reduced, the more must the angular velocity be increased.

Suppose that we have such a turbo-compressor formed of four rings of vanes of decreasing diameter in series, of which the largest has a diameter of 320 mm. (12.6 in.). The peripheral speed which the large wheel must realize being 500 meters (1640.4 ft.) per sec., the rotor must turn at a speed of 30,000 r.p.m. A mass weighing 1 gram. (0.0022 lb.) placed on the periphery of the large wheel would be subject to a centrifugal force of 160 kg. (352 lb.).

In order to construct vanes able to resist forces of this magnitude, while at the same time sufficiently light, Mr. Leblanc has employed threads of ramie stretched parallel and consolidated by dissolved cellulose.

It is further necessary that the shaft and the rings of fiber vanes (constituting the rotor) be balanced in such manner that the axis of figure shall coincide with the principal axis of inertia. Mr. Leblanc has achieved this by the use of automatic equilibrators constituted by the use of hollow tori partially filled with mercury. Further the rotor is carried on very light bearings, themselves resting on springs very supple and of small mass.

A compressor of this type is still under experimental development. So far as known, it has not yet been introduced into practical use.

IV.—APPLICATIONS OF REFRIGERATION

1.—THE TRAVELING REFRIGERATING PLANT OF THE FRENCH ASSOCIATION DU FROID

The French Association du Froid has developed the plan of a traveling refrigerating plant in order to demonstrate on the spot to agriculturists the advantages which may be realized by the use of refrigeration. To this end it has built, with the aid of various French manufacturers, a special car constituting a veritable

traveling refrigerating plant, which it proposes to locate, for the time, in various regions of France.

This car is divided, by transverse partitions, into three compartments. In the center a room for the machinery and at each end a refrigerator room.

The room for the machinery is 2.48 m. for 2.39 m. by 2.28 m. high (8.15 ft. by 7.85 ft. by 7.5 ft. high) at the center, and 1.96 m. (6.4 ft.) high at the sides. Ventilation is assured by means of the door placed at the center of the car, and by a movable shutter in the wall opposite the door.

The two cold rooms are of different dimensions. One, called the refrigerator room, measures 2.25 m. by 2.27 m. (7.35 ft. by 7.45 ft.); the other, called the freezing room, measures 2 m. by 2.27 m. (6.56 ft. by 7.45 ft.). Both have a height of 1.8 m. (5.9 ft.). Access to these rooms is obtained by way of two doors constructed in the partition opposite to that in which is located the door of the machinery room.

The refrigerating machine is of the Audiffren-Singrün type, with a capacity of 1500 frigories per hour. It is driven by an explosion motor of 4 hp. running at 400 r.p.m. and using benzol as fuel. The tank of brine in which is plunged the refrigerating shell of the machine is provided with a distributing header. The circulation of the brine is furthermore realized by means of a pump.

The insulation of all the walls of the car has been made with especial care. It has been planned with a view of reducing the loss of heat to an amount not exceeding 0.5 calorie per square meter per hour (0.184 B.t.u. per sq. ft. per hr.).

This insulation is made up as follows:

Outer walls of car—from interior to exterior.	
Wood	15 mm. (0.59 in.)
One thickness of insulating paper	
Wood	15 mm. (0.59 in.)
One thickness of insulating paper	
Cork in sheets	40 mm. (1.58 in.)
Wood	25 mm. (0.99 in.)
Cork in sheets	50 mm. (1.97 in.)
One thickness of insulating paper	
Cork in sheets	50 mm. (1.97 in.)
One thickness of paper and wood	20 mm. (0.79 in.)
Partitions separating the refrigerator rooms from the machinery room.	
Wood	15 mm. (0.59 in.)
One thickness of insulating paper	
Cork in sheets	120 mm. (4.73 in.)
One thickness of insulating paper	
Wood	15 mm. (0.59 in.)
Floor—from interior to exterior.	
Two thicknesses of boards of 20 mm., each laid with broken joints	40 mm. (1.58 in.)
One thickness of insulating paper	
Cork in sheets	100 mm. (3.94 in.)
One thickness of insulating paper	
Wood	20 mm. (0.79 in.)
Ceiling of car.	
Wood	25 mm. (0.99 in.)
Covering on inside	
Cork	100 mm. (3.94 in.)
One layer of insulating paper	
Wood	20 mm. (0.79 in.)
Covering on outside	
Cork	50 mm. (1.97 in.)
Wood	15 mm. (0.59 in.)
One thickness of felt	
One layer sheeting soaked in bitumen.	

The cooling of each of the two rooms may be effected either by the circulation of brine, or by the circulation of cold air, or by both methods together. It is, in fact, necessary to make, between — 10 deg. C. and + 10 deg. C., the various demonstrations regarding the products which may be preserved by refrigeration—such as meat, fish, fruit, flowers, vegetables, butter, eggs, etc.

The brine (solution of chloride of calcium) is sent into holders, three of which are placed in each room. Each of these is made up of nine tubes of 10 cm. (3.94 in.) diam. and 1.60 m. (63 in.) long. There is therefore in each refrigerator room about 350 liters (92.4 gal.) of brine.

Furthermore, in the upper part of each room is arranged a space 36 cm. (14.2 in.) high by 1.6 m. (63 in.)

wide separated from the rest of the room by a partition composed of two thicknesses of board with 60 mm. (2.36 in.) of sheet cork between them. This space contains the refrigerator coils. The air is sent over these refrigerating coils through an exhaust conduit, circulates in the refrigerator room and is drawn out through other conduits by means of the ventilator. The air conduits which traverse the machinery room are made of two thicknesses of wood separated by a layer of insulating paper.

All piping which carries brine to the containers and to the refrigerating coils is insulated with consolidated cork chips 40 mm. (1.58 in.) in thickness.

Experiments were commenced with this traveling plant, but unfortunately they have been interrupted by the war. Nevertheless, the results thus far obtained show that this manner of demonstration will, in the future, be of great service.

2.—REFRIGERATION IN THE WINE INDUSTRY

Among the applications of refrigeration, one which, in France, in recent years, has attracted especially the attention of savants, is the treatment of wines by low temperatures.

The second French Congress of Refrigeration, held at Toulouse in September, 1912, at the suggestion of the French Society of Refrigerating Engineers, decided on the formation of a sub-committee on the applications of refrigeration in the wine industry. It is charged with the duty of grouping, in the principal grape-growing regions of France, chemists, proprietors, dealers

and growers who might be disposed to interest themselves in the various applications of refrigeration for the treatment of musts, of wines, brandies, liqueurs, ciders and aperitifs with a wine base.

Even before the constitution of this sub-committee, reports on various important investigations regarding this question had been published by Dr. Carles of Bordeaux, and by Mr. Mathieu, director of the Oenological Station of Bourgoyne. The purpose of the new committee was to group the results of these various investigators and to give definite scientific indications regarding the effects of refrigeration in the wine industry.

The Committee of the South West installed at Bordeaux, has already made known a certain number of results which we give here in résumé.

It has long been known that, subjected in winter to the prolonged action of cold (without going to congelation), new wine undergoes more rapidly a spontaneous normal purification. This effects a number of constituents such as the least stable part of the color, the nitrogenous and mucilaginous matters, organic and mineral salts. It is known also that the precipitation of cream of tartar forms the most important of the deposits, and that it produces a corresponding reduction in the acid content which, joined to the loss of the tannoidal substances, results in a diminution of the rough taste of new wines. To this improvement in the taste must be added the arrest of ferments due to anaerobic bacteria which are almost always present in new wines, an arrest which favors their ulterior elimination and, in consequence, the normal preservation of the wine.

Nature of Installation	Total No. of Installations	Installations with Ammonia Machines Capacity in Refrigerators per Hour	Installations with Sulphur Dioxide Machines Capacity in Refrigerators per Hour	Installations with Carbon Dioxide Machines Capacity in Refrigerators per Hour	Installations with Methyl Chloride Machines Capacity in Refrigerators per Hour	Installations with Water Under Vacuum Capacity in Refrigerators per Hour	Total Refrigerating Power in Refrigerators per Hour	Remarks
I. Ahtatoirs.....	32	19 1,950,000	9 50,000	1 8,000	2 124,000	1 150,000	2,282,000	57 machines
II. Wholesale grocers.....	49	32 764,000	8 172,000	6	3 34,100		970,100	48 machines
III. Meat shops.....	116	40 216,880	57 142,100	14	6		minimum 258,980	for 42 install.
IV. Breweries.....	445	118 7,851,500	262 8,741,500	63 4,260,000	2		20,853,000	91 machines
V. Pork packers and cooked meats.....	58	15 444,000	31 375,000	10	2		minimum 819,000	for 91 install.
VI. Chocolate shops.....	77	46 518,000	19 139,000	7 70,000	5		minimum 727,000	
VII. Confectioners and pastry shops.....	15	5 34,500	9 12,600	1			minimum 47,100	
VIII. Distilleries.....	9	4 380,000	4 41,000		1		minimum 421,000	
IX. Cold storage establishments.....	124	40 3,039,100	34 126,700	16 316,000	5		minimum 3,451,000	
X. Storage vaults for wine and beer.....	8	2 23,000	4 240,000	min.	min.		263,000	9 machines
XI. Ice plants (domestic use).....	686	194 11,462,000	276 2,257,000	59 1,193,000	156	1 4,000	minimum 14,916,000	
XII. Ventilation of mine shafts.....	9	9 20,400,000					20,400,000	77 machines
XIII. Cheese factories.....	38	30 1,029,000	6 60,000		2 2,000		1,091,000	
XIV. Cold storage of fruit.....	8	3 112,000	4 6,500		1		118,800	
XV. Hotels, taverns, restaurants.....	67	11 87,000	29 145,000	14 15,000	12 10,000		257,000	1 install. with air expansion machine
XVI. Chemical and pharmaceutical industries.....	142	57 2,593,000	19 326,000	21 566,000	38 89,000	7 1,192,500	4,766,500	160 machines
XVII. Horticultural establishments.....	3	min.	3 18,500	min.	2		15,500	
XVIII. Laboratories.....	38	4	20	min.	2			
XIX. Milk and cheese industries.....	187	30 541,000	40 231,000	71 682,500	46		1,454,500	132 machines
XX. Morzuos.....	7	4 90,400		1 15,000	2	36,000	116,400	
XXI. Sanatoria.....	11	1 3,000	9 17,100		1		20,100	
XXII. Wine and liquor industries.....	27	5 115,500	11 132,600	2 92,000	9		340,100	26 machines
Total.....	2156	669 51,653,880 31.2%	854 13,233,900 70.0% 39.9% 18.0% about	250 7,217,500 13.5%	297 295,100 0.4%	9 1,346,500 0.4%	73,746,080 minimum	

MARINE AND RAILWAY

I. Ammunition rooms.....	28		7 540,000		21 1,012,000 for 58 machines	2,452,000
II. Refrigerating ships.....	82					
III. Refrigerating cars.....	360 about					

In short, wine subjected to cold is refined more rapidly and may, in consequence, be presented to the trade after a shorter period of ripening.

Those results of the action of cold were, until quite recently, empirical. There had been scarcely any systematic attempt to scientifically study their production and control.

The experiments made by the Bordeaux Committee, although limited to a small number of wines, enable us to say that the principal advantages attributed to natural cold may also be realized by means of artificial refrigeration.

The application has been made in two ways.

1. *Rapid Refrigeration and Short Period of Application of Cold.*

The wine is rapidly cooled to a temperature of -5 deg. C., first in a receptacle cooled by wine already cold, then by circulation around a serpentine filled with a refrigerating fluid. This cold wine remains then about a week in vats of 50 hectoliters (1320.8 gal.) insulated thermally and cooled inside by a coil carrying a current of refrigerating fluid.

2. *Slow and Prolonged Refrigeration in Rooms Kept at Temperatures About 0 Deg. C. and -3 Deg. C.*

Casks are introduced into the cold rooms in a storehouse and left there during a considerable time (in the actual case about four months).

The results obtained by these methods indicate that the treatment by rapid refrigeration gives less favorable results than the prolonged treatment does in cold rooms.

However, the treatment lasting four months constitutes scarcely an economic treatment. Further experiments should be undertaken in order to see if the maximum effect may not be obtained at the end of shorter period of time. Furthermore, the present experiments have not made it possible to discriminate between the temperature 0 deg. C. and -3 deg. C.

Further experiments should be made to elucidate this new question.

Paris, France.

Pure and Applied Chemistry.—In a paper presented before the Second Pan-American Congress in Washington, Dr. F. W. CLARKE pointed out that the earliest chemical data were obtained empirically, mostly by accident, and in the slow development of the arts. As such data accumulated, men began to reason about them. chemical doctrines were evolved, which, however, had little or no real validity. The atomic speculations of the Greeks were unfruitful, and led to no real advance. The atomic theory of Dalton was different. It was quantitative, it correlated known relations, and founded our present system of chemical formulas, chemical equations, and chemical arithmetic. From those additions to our knowledge chemical industries have derived much profit. The theory of valency and the benzene ring of Kekulé were outgrowths of Dalton's discoveries, and have guided practically all of the researches into coal-tar chemistry, with its dyes, medicines, and explosives. This union of theory and practice is characteristic of scientific chemistry. Between pure and applied chemistry the difference is one of purpose, of motive. The search for truth itself on one side, the utilization of the truth on the other. Discovery, however, must precede use. On the other hand, applied science stimulates research and each aids the other. Endowed laboratories should be established, in which corps of trained men should work together on problems that are too great for individuals to handle. Co-operation among chemists is needed in order that science may grow more symmetrically and systematically.

The Recovery of Wool Fat

BY EUGENE E. AYRES, JR.

It is estimated that in the vicinity of Philadelphia alone from five to ten thousand pounds of wool fat are being thrown away every day of the year. The recovery of this fat is becoming more and more important to wool scourers for several reasons, the chief of which is the abnormally high price of a reasonably good product. The purified fat, "lanolin," has hitherto been imported from Germany, as the market in this country has never been very great, but the partially purified "neutral wool fat" has always been in great demand.

The wool scouring plants in the thickly populated countries of Europe are compelled by rigorous legislation to remove all grease from their scouring waters, and they have succeeded in developing quite an adequate market. Germany and France produce a relatively enormous amount of wool fat, and have been disposing of it in various ways. Some is subjected to a purification process, by which all odor and nearly all color is removed. This product is put up either in anhydrous form or in thick emulsions as a toilet preparation, for "lanolin" is known to be exceptionally beneficial in its action on the skin. The general market for the commercial "neutral wool fat" is well known. Some of the cruder fat is converted by destructive distillation to an illuminant, "Fettgas." Some of the wool fat is distilled under pressure to obtain a pure white paraffine-like substance, the utilization of which is not generally understood in this country. Our personal acquaintance with the demand for wool fat is not specific but general. We have been in touch with many industries who are very anxious to get hold of comparatively large amounts.

The literature on wool fat is confusing, for each investigator has worked with samples that were obtained by different methods of scouring, recovery, and purification. Moreover, the fat will always vary in composition according to the source. The fat content, as determined by gasoline extraction of various wools, will vary from 5 to 25 per cent, depending on the breed and health of sheep, locality, and treatment before shearing.

Broadly speaking, less than 1 per cent of neutral wool fat is saponifiable under ordinary conditions. The crude fat as it comes from the wool contains some lower fatty acids already saponified by the action of soda ash in the scouring water and also some fatty acids (from acetic to caproic) that result partly from fermentation, and partly from the action of heat in breaking down some of the more complex esters. As the scouring waters are alive with bacteria, it is well to keep the temperature high enough to prevent fermentation, but not so high as to decompose the fat.

It is plain that the recovery of wool fat involves not only a separation from the scouring water, but also from soaps and the lower saponifiable fatty acids.

Wool fat is very soluble in all ordinary organic solvents, except ethyl and methyl alcohol. At 20 deg. C. ethyl alcohol dissolves about 0.5 per cent. The solubility in methyl alcohol is much less. The relative insolubility of wool fat in alcohol has been used as a means of purifying from fatty acids, but unless a powerful centrifuge is used, the treatment is possible only when no soaps are present, for a trace of soap will cause a very complete emulsion.

There are two processes for wool scouring. One, which is little used in this country, involves a gasoline extraction of the wool fat. The solvent is distilled off and the product, containing all impurities, is sold as "de gras." The more common procedure is to wash with a weak aqueous solution of soap, soda ash, and am-

monia. The wash waters contain the wool fat emulsified and soapy impurities in solution. The wool fat may be recovered simply by maintaining a temperature of about 140 deg. Fahr. The fat from some sources will separate over night, but usually several weeks will be required. A study of this severe emulsification brought out the fact that it is caused by the presence of the soap in conjunction with certain unidentified impurities in the wool fat. Pure lanolin will not emulsify to any great extent with these weak soap solutions.

The wool fat can be separated by precipitating all soaps by the addition of lime or of calcium chloride, but the recovery of fat from calcium soaps is a rather expensive extraction proposition. The wool fat can also be separated by precipitating the fatty acids with hydrochloric or sulphuric acids. The fatty acids, which are highly soluble in wool fat, are exceedingly difficult to remove, and can be neutralized only in alcoholic or aqueous solution, with formation of a soap emulsion.

The most natural process must, of course, be found in the proper application of centrifugal force. No better wool fat can be prepared than by successive gravity separations in the laboratory, but gravity is too slow. Recently, considerable work has been done on the commercial recovery of wool fat by centrifugal force. The selection of the proper type of machine was the essential factor. The qualifications were these: the delivery of melted fat must be continuous; the separation must be equally efficient for any percentage of fat; the separation must be efficient for the lowest temperature possible. By the courtesy of the Sharples Specialty Company a continuous centrifuge was provided that fulfilled all these conditions. It was found that a scouring water containing 1.55 per cent of wool fat yielded 1.45 per cent, each machine yielding from 10 to 11 lb. of fat an hour. The temperature was 140 deg. Fahr. The product was light yellow, contained little water and offered fewer purification difficulties than the fat from any other recovery. It developed that by increasing the volume of scouring water the efficiency of separation was considerably reduced, and that by decreasing the volume, the efficiency was not improved. A number of scouring waters from different sources gave somewhat different figures, but the figures above should be fairly representative.

The purification of wool fat can be effected by a combination of washing and chemical bleaching agents. The elimination of odor depends not on the actual removal of the odoriferous substances, such as butyric or caproic acids, but on their oxidation, reduction, condensation, or hydrolysis. Large volumes of water will effect hydrolysis to a certain extent. Here again a centrifuge is indispensable. Dilute sulphuric acid will improve the odor to a marked degree, possibly by condensation of the odoriferous components, but the fat will be darkened.

Of all the bleaching agents tried, sulphur dioxide appears to give the best results when properly applied. Chlorine, in nascent condition, has also been successfully used.

In view of the generally awakened interest in the recovery of by-products, our experiments should prove of some interest. If it should ever be desired to completely purify our scouring waters, 90 per cent or more of the fat can be removed in nearly pure form, and the other 10 per cent can be precipitated and discarded with impurities by adding a trace of acid and passing through a proper type of centrifugal. The profit from such an operation would be far in excess of the costs, whereas a recovery by precipitation can never be made to pay for the expense of equipment and operation.

West Chester, Pa.

The Raw Materials of the Blast Furnace

BY J. E. JOHNSON, JR.

The raw materials for the production of iron are three, the ore, the fuel, and the flux. Fuels have already been described in the introductory article of this serial and flux has received all the discussion necessary in the article on chemical principles. We have, therefore, only to deal with ores which, as already explained differ in the case of iron from those of any other metal in that they are exclusively the oxides.

Oxides of iron found in nature are three in number, ferric oxide Fe_2O_3 , hydrated ferric oxide $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$, and ferric ferrous oxide Fe_3O_4 , commonly known as magnetic oxide or magnetite.

There is a fourth oxide, ferrous oxide FeO , but it does not occur in nature under ordinary conditions for the reason that when produced it instantly absorbs oxygen from the air or any other source and converts itself to ferric oxide Fe_2O_3 .

It is a matter of much geological importance as affecting the origin and cause of iron ore deposits that iron in the ferrous condition is soluble in water containing carbonic acid and in dilute solutions of vegetable acids.

The only ferrous condition in which we ordinarily find iron is as the carbonate. This occurs in nature in great quantities. Its solubility in water containing carbonic acid is not so great as that of limestone, and when an iron-bearing solution meets a body of limestone the iron is deposited and the more soluble limestone removed.

It is probable that an action of this general nature has been responsible for the existence of a large percentage of those iron concentrations in nature which are commercially known as ore deposits; though in most of such cases the iron has undergone a process of subsequent oxidation which has left the iron as ferric oxide sometimes hydrated and sometimes not.

There are no deposits of carbonate of iron in the United States now being worked on a commercial scale, though in the Lake Superior region there are vast deposits of lean carbonate which may eventually, by concentration or otherwise, come into commercial use.

There are, however, very large deposits of iron carbonate on the Canadian side of Lake Superior which promise to become of much commercial importance to the iron industry of Canada. These ores are unusually high in manganese and quite high in sulphur. It is necessary to eliminate both the sulphur and the carbon dioxide, the latter because its weight is about 30 per cent of the total so that the freight is correspondingly reduced by its removal, and because the coke solution loss caused by the liberation of this carbon dioxide in the furnace would be ruinous.

The removal of both objectionable components is effected by roasting and the resulting product contains over 50 per cent iron and unusually low phosphorus about 0.010 per cent.

The gangue of the ore consists very largely of lime and magnesia, so it is more than self-fluxing, which is a great advantage, while its physical condition is excellent as it is crushed to small lumps almost free from fines, and retains that condition after roasting.

The black-band iron ores which occur in some coal fields and which were formerly successfully worked in western Pennsylvania are impure carbonates, but these are no longer in commercial use, having been superseded by richer and cheaper ores. In Europe, in England especially, there are great bodies of iron carbonate. The iron industry of the Cleveland district in England is founded on a great deposit of this material,

locally known as "clay iron stone," and there are some deposits of great commercial importance on the continent of Europe.

LIMONITE

Limonite is a term commonly employed in commercial usage to describe all the common hydrated oxides of iron, of which there are three, turgite, goethite, and limonite, containing different quantities of water of crystallization ranging from 5.3 to about 14.5 per cent. This is the only distinction between them, and as limonite is much the more common in nature this name is applied to all three indiscriminately. They are also known generically under the name of brown ores, that being their characteristic color and the color of the "streak" which they yield under that geological test. The chemical formula for limonite is $2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ and its content of iron when pure is therefore 59.85 per cent.

Brown-ore deposits are probably more numerous than those of any other ore. There is hardly one State in the United States which has not deposits of sufficient size to be worked were the commercial conditions ordinarily favorable, but they do not ordinarily occur in as large masses as the magnetites and hematites.

The principal districts where such ores are now commercially mined in America are in western Massachusetts and Connecticut and eastern New York, eastern and central Pennsylvania, the western portion of Virginia, the central and western portions of Tennessee, the northwestern portion of Georgia, the northern portion of Alabama and northeastern Texas where limonite bodies of great commercial importance have recently been developed.

There are deposits of ore of this kind in various Western States, but on account of the unfavorable commercial conditions for the iron business on the Pacific slope no limonite ore bodies are at present in operation there on an important scale.

There are also brown-ore bodies of importance in the Lake Superior district, but those are not generally so highly hydrated as those in eastern and southern portions of the country, and for this reason, presumably, they are commonly not spoken of as limonites, but as "brown hematites."

In the Lake Superior district the ores range all the way from true hematite to true limonite, but the hematites predominate and for this reason give their name to all the ores of this class.

Limonite occurs as the immediate result of the oxidation of iron carbonate or other ferrous compound deposited by circulating water which carries the required oxygen. It may frequently be seen in the actual process of deposition at the present day, the best known illustration being that of the "bog ores." Streams carrying much vegetable matter in a region of ferriuginous rocks dissolve the iron from these rocks and carry it in solution as a carbonate; or in combination with vegetable acids, to a lake or marsh where it has time to absorb oxygen from the atmosphere. This oxidizes it to ferric oxide which absorbs from its surroundings the necessary water of combination to convert it into limonite. This settles to the bottom and cements itself together as a true ore deposit.

The purity of limonite varies greatly and within short distances, even in the same mine, its content of phosphorus fluctuating considerably, but not as rapidly as that of silica which may range all the way from 3 or 4 per cent to 25 or 30 per cent without greatly affecting the appearance or even the specific gravity of the ore in certain conditions.

This ore is ordinarily low in sulphur, probably because of its aqueous origin and for the reason that the process of oxidation which converted it from the fer-

rous to the ferric form simultaneously oxidized any sulphur which it may have contained and so facilitated its removal in solution. These iron ores are commonly not so low in phosphorus as many others, limonite below the Bessemer limit in phosphorus being comparatively rare. A typical analysis of southern limonite as far as so variable a material can be said to have one is iron 45-48 per cent, silica 10-22 per cent, alumina 2-4 per cent, manganese 0.3-1 per cent, phosphorus 0.2-0.5 per cent, sulphur trace, combined water 9-11 per cent.

The principal characteristic of limonite in the blast-furnace is its extreme reducibility. The water of hydration begins to be driven off at quite a low temperature and is completely removed at 800 or 900 deg. Fahr. It is commonly believed that the driving off of this water facilitates the access of the gas to the interior of the ore and while the ore shrinks more in volume than it does in weight from dehydration, thus indicating that no porosity is developed thereby, its action in the furnace lends color to this belief, since it is the most reducible material with which the blast furnace ever has to deal. It is highly valued on this account particularly for admixture with less reducible ores on which it seems to exercise a beneficial effect.

HEMATITE

The ores embraced under this designation constitute the source of more than 80 per cent of the iron produced in America. Their origin is less obvious than that of the limonite, but it seems certain that in very many instances they were deposited originally as limonites and subsequently dehydrated by conditions of temperature and pressure resulting from some of the more important geological actions of the earth's crust.

The largest known deposits of iron ore in America and probably the greatest number of large deposits are hematites, but this name is employed to denote material covering a wide range of characteristics. As has already been mentioned, the partly dehydrated limonites of the Lake Superior region, which range from yellow to dark brown in color, are classified as hematites. The geological "streak" of true hematite is blood-red and that is its most common color. But it varies from the light yellow of the partly dehydrated limonites of Lake Superior on one hand to the blue-black ores which, still carrying the same name, have been partly converted presumably by still further heat and pressure, into magnetites. It also varies in physical structure from the "soft" ore almost without hard particles and nearly as plastic as clay itself to a dense crystalline structure so hard that a steel drill will scarcely attack it, and from a lumpy mass in which fines are almost absent to great deposits of such fineness that 75 per cent or more will pass through a hundred-mesh sieve. As to its content of impurities it is equally as variable, ranging from bare traces of sulphur and phosphorus to a sufficient quantity of these elements to bar its use as a furnace material.

The principal districts in which these ores are commercially mined in America are, first, the Lake Superior region; second, the Birmingham, Ala., district, and third, a district in Colorado and Wyoming which serves the plant of the Colorado Fuel and Iron Company.

The Lake Superior region is divided into five main ranges, as follows: The Marquette, the Menominee, the Gogebic, the Vermillion, the Mesaba and the Cuyuna, this being their order from east to west and approximately also the order of their chronological development.

These five ranges constitute probably the largest body of rich iron ore in the world, shipments being made from them at the rate of nearly 50,000,000 tons per

year with sufficient ore in sight to maintain this rate for many years to come.

The predominating characteristics of the ores from the different ranges vary considerably. All the Marquette and Menominee ores are either lumpy or soft, seldom or never fine like sand. The ores of the Gogebic are almost wholly "soft" or clay-like. The ores of the Vermillion are almost entirely extremely hard, there being virtually no soft and no fine ore. The ores of the Mesaba are almost without exception fine, seldom or never lumpy to any great extent and while sometimes clayey never so much as those of the Gogebic. The finest ores commercially used anywhere come from this range. The ores of the Cuyuna embrace all three varieties to some extent, but its discovery is so recent and its development so incomplete that it is not possible to say positively what the predominating characteristic of its ores will be.

The characteristics of these ores for use in the furnace depends in great measure on their physical structure. The hard, lumpy ores are less reducible than the fine and sandy or the soft ores, but are highly valued because the looseness with which they lie in the furnace permits the passage of the furnace gas through them much more easy than do the fine or the soft ores. The soft ores are characterized by high reducibility, and on account of their plastic nature are not much subject to being blown out of the top of the furnace by the gas current. On account of presenting less surface to the action of the gas than the extremely fine ores the initial changes in their condition occur more gradually and the furnace works better in consequence. Because of these characteristics, these ores are among the most highly valued of all varieties.

The fine ores present neither the free passage for the gas offered by the hard lump ores nor resistance to being blown out of the furnace like the soft ores, while the vast quantity of surface which they expose to the action of the furnace gas causes the initial reactions to take place in them with great velocity, thus further increasing their fineness and so rendering them still more likely to be blown from the furnace. Moreover, they tend to cause excessive solution loss. For these reasons it was almost impossible for furnaces to work on large percentages of these ores in the early days of their use, and even with the increase in knowledge of how to handle them they are still much less desirable than coarser or more plastic ores.

FERRIC FERROUS OXIDE OR MAGNETITE

The chemical formula of this oxide is Fe_3O_4 , and its theoretical percentage of iron is therefore 72.4, higher than that of any other oxide of iron occurring in nature. Ores of this nature appear to have originated in three separate and distinct ways.

First, by a continuation of those conditions of heat and pressure which dehydrated limonite and converted it into hematite; these if carried far enough seem to have converted hematite in its turn into magnetite.

Second, this ore appears to have originated in many cases as a segregation from a mass of molten igneous rock; an igneous origin is attributed to some of the largest known bodies of magnetite.

Third, it is chemically possible to deposit magnetite from an aqueous solution of certain iron salts and it is possible that this may have been the origin of some ore deposits of this kind. This ore when approximately pure is distinguished by its intense black color and high specific gravity, also by its strong attraction for the magnetic needle. This is so great that the compass cannot be used for ordinary surveying in districts where there are considerable deposits of this ore. On

the other hand, the deviation of the needle from its proper bearing, determined by the solar compass, indicates the presence of bodies of magnetite under the ground, though these are not necessarily of commercial importance on the strength of such indications. A special compass is used for this purpose in prospecting work to some extent.

Its magnetic condition gives this ore an important advantage over other ores since this makes it relatively easy to concentrate by magnetic separation from its gangue so that deposits of magnetite can be worked and rendered commercially available when lower in iron than can be permitted with non-magnetic ores. In addition to the relatively harmless gangue, elements are frequently removed in the concentration which would exercise a deleterious influence on the quality of the iron if it remained in the ore. This is particularly true of magnetites containing phosphorus. Lean ores high in phosphorus in their crude condition can in some cases be concentrated to Bessemer ores of exceptional purity. The process of magnetic concentration has been more highly developed in the Lake Champlain district in New York than anywhere else in the United States.

In its action in the furnace this ore differs greatly from limonite and hematite. It is generally much more dense than either of these and resists the reducing influence of the furnace gases, even at temperatures at which the other ores are almost completely reduced. For this reason a large portion of its oxygen can only be removed from this ore with solid incandescent carbon in the lower regions of the furnace. These conditions require that more time be given for the reduction of this ore than is necessary with the other varieties and in consequence the output of a furnace on a burden of this ore is smaller and its fuel consumption higher than those of a furnace using a hematite of similar composition and physical characteristics.

In addition to these natural ores of iron there are various iron-bearing materials which owing to their mechanical condition, or their mechanical composition, are not suitable for charging into the furnace in the condition in which they occur. These may be natural ores of abnormal composition or condition, or they may be the by-products of another industry.

Ores in many districts occur in conjunction with foreign materials which can be removed from them by simple means, this often rendering suitable for furnace use a material which it would be impossible to consider using in its native condition. Perhaps the most notable instance of this is the brown ores or limonites which, in a great if not preponderating proportion of mines, occur admixed with heavy clay and sand to an extent that renders the native material entirely unfit for the furnace, but by a simple process of washing with water, by means of vigorous agitation, the foreign material may be removed and a very desirable ore produced. Of all the limonite ores in the country it is probable that 90 per cent are so washed before they are used. In other cases these ores, and sometimes others, are admixed with pieces of barren rock, but so intimately that while in the larger sizes separation can be effected by hand-picking, in the smaller sizes it is necessary to use jigging, and various jigs have been developed which are extremely successful for this purpose. Probably the largest washing and jigging apparatus in the world is that at Coleraine on the Western Mesaba field where some 25,000 tons of material a day are handled, which are entirely unfit for blast furnace use as received, but from which some 15,000 tons of excellent ore are recovered.

Magnetic ores are often, if not generally, mixed with barren rock, and this being non-magnetic the ore can

quite easily be removed from it by magnetic separation. In order to make this feasible the material must be crushed to a degree of fineness which depends upon the intimacy of mixture between the rock and ore. The ores of Lake Champlain are particularly well adapted to this treatment, the individual mineral particles are quite large in the case of both the rock and the gangue, and being distinctly crystalline the minerals tend to separate at the crystal faces. This favorable condition combined with the enterprise of the owners has resulted in the development of magnetic separation at these mines on a large and very successful scale. In other mines such as that at Cornwall, Pa., the intimacy of the mixture is much greater and much finer crushing is required, while at the Moose Mountain mine in Canada the crystals are so small and so intimately mixed that the ore has to be ground almost as fine as flour before a satisfactory separation can be secured. This fine grinding brings the ore into the condition of other fine iron-bearing materials of which there are two principal classes, flue dust produced by the mechanical carrying over of the fine particles of the charge by the gas current, and pyrites cinder, commonly known as "blue billy," the residuum which is obtained from finely ground pyrites used for the manufacture of sulphuric acid. This material like the fine concentrates of the Cornwall mine contains from 1 to 2 per cent of sulphur; this with their fineness makes them an undesirable ore burden from the operating point of view because they are liable to a very heavy loss of the ore itself by blowing over; because they cause high solution loss, and therefore relatively high fuel consumption as already described, and because they have a tendency to travel ahead in the furnace, build up on the bosh walls, and then slide off in masses of sufficient size to put the furnace almost out of business, while the sulphur necessitates a limey slag and therefore still further raises the fuel consumption. For all these reasons then these ores must receive another treatment. Fine ones may be agglomerated or stuck together by processes not involving the use of heat, but for sulphurous ores some sort of roasting is desirable, if not absolutely necessary to get rid of the sulphur, and this operation can be carried on at a sufficiently high temperature to frit the ore, and stick the particles together in a plastic condition.

For the purpose of binding together fine ore without roasting various processes have been proposed and used. Ore has been mixed with cement, the setting of which stuck it together in lumps which could be charged back into the furnace. Clay has been used for the same purpose, but most of these cold processes depend upon the production of briquettes by pressure in combination with the use of a binder in some description.

In the scoria process ground hydrated furnace slag is used, and after the briquettes are formed under heavy pressure they are baked with high-pressure steam for several hours in a steel retort so that a further hydration takes place and the slag sets, acting as a binder.

The Schumacher Process makes use of the fact discovered by Dr. Schumacher in Germany that certain substances have a catalytic action on flue dust which causes it to set and harden somewhat like cement. Magnesium chloride and ferric sulphate are two of the substances successfully used for catalyzers. The quantity used, and its cost, are not sufficient to cause a heavy charge against the product, while the quantity of sulphur introduced with the ferric sulphate is not sufficient in amount to effect the use of briquettes in the furnace in ordinary proportion. More recently it has been found that the fine dust separated from furnace gases by the Halberger-Beth system also had this catalytic power, and briquettes are being made with this

material to contribute the cementing property, but not, as far as known to me, in this country.

All these briquettes are liable to disintegration if exposed to the weather, and if they are to be stored must be put under cover, otherwise they will decrepitate to a detrimental extent in a comparatively short time. A further fact to be considered in connection with them is this: they consist of the original particles of dust bonded together perhaps quite firmly, but still separate particles, with bonds capable of dissolution. The decomposing tendency of furnace gas on iron-bearing materials has been many times set forth. How far then will these briquettes progress down in the furnace before they are decomposed by the action of the furnace gas itself, and so returned to that objectionable condition of fineness which is one of the most important reasons for agglomerating them in the first place?

If this action takes place well above the top of the bosh we may have the high solution loss which it should be the principal function of agglomerating to prevent. Some effort has been expended by the advocates of these systems to prove the reducibility of their product, but if it be true, as I have shown in an earlier chapter, that a furnace may suffer as severely by too great reducibility of the ore as by too great irreducibility, the results of their efforts are not convincing. They may in fact be proving the very condition which would be worst.

Turning now to the processes of agglomerating by heat we have four which in the order of their development are the rotary kiln, like a cement kiln, usually fired with powdered coal, the up-blast converter pot of the Huntington-Heberlein type and the down-draft pot or pallet, and the tunnel furnace of the Gröndal type in which briquettes formed under pressure are burnt to strong and durable condition.

The fuel required for the first is about 15 or 20 per cent of the weight of the material agglomerated, when the latter is carbon-free material such as fine ore or bluebilly, but a less percentage in the case of flue dust. The up draft converter or pot is an apparatus not unlike a Bessemer converter with a grate in the bottom through which a strong current of air is forced by a positive pressure blower. A fire is built on the grate and this is covered over, when well started, with flue dust or ore (though this process has been used principally for flue dust), taking care so to place the material as to stop up the holes in the bed, and produce as nearly as possible a uniform blast over the whole surface. A little coal is thrown in from time to time with the charge, the air continuing to force its way from the bottom upward through the porous material formed. Only enough coal is charged to bring the material to a sticky condition so that the individual particles are partly fused together, and the blast blows holes through the mass while soft, making it spongy. When the pot is full it is tipped like a converter and the resulting "chunk" of sinter of many hundred pounds weight is broken up partly by its drop onto a grating and partly by hand sledging.

In the down draft apparatus a grate is provided at the bottom, but as the products are drawn down through the bed and reach the grate in their hottest condition it has been found necessary to cover the grate over with some harmless substance which protects it from the severity of the hot gas to some extent.

There are two down-draft processes, the Dwight-Lloyd and the Greenawalt. In the first an intimate mixture of the material to be sintered with as much fine coal or coke as may be necessary for the operation is spread upon the grate in a uniform and homogeneous layer. The top surface is ignited by a flame which plays upon it for a short time, and the down draft

through the mass pulls the plane of combustion gradually down to the bottom of the mixture, stopping on top of the inert material on the grate, this material being generally limestone spalls, which are not only harmless but are needed in the charge any way, and whose partial calcination is that much advantage to the furnace.

The difference between the Greenawalt and the Dwight-Lloyd processes is briefly that the former is a batch or charge process, one definite quantity being handled at each operation, whereas in the Dwight-Lloyd system the operation is continuous, the apparatus being in substance no more than a chain grate arranged for down draft. Both types of apparatus have their champions, and each claim advantages over the other, but they are very similar in principle and in product, so that eventually that one will probably win which can show the lowest operating cost. Both these types of apparatus produce a very desirable product. It is even more spongy than that of the up-blast pot while owing to the uniformity and better preparation of the charge before combustion begins a much larger percentage of properly sintered material is produced. The exposure of all the particles to the blast is excellent, and in consequence the desulphurization is good. Monthly records have been made in which blue billy ranging from 1 to 4 or 5 per cent in sulphur was reduced in the sinter to a very uniform figure of about 0.1 per cent.

The great advantage of the down draft over the up draft for sintering is that with the up draft the surface particles are in a constant state of agitation, than which nothing could be more unfavorable to sintering them together without producing an unduly pasty or liquid condition. In the down-draft apparatus, on the other hand, the surface layer, as well as all the other layers below it, are held in place by the passage of the blast through them. The agitation of the charge during sintering is, therefore, entirely eliminated and a larger percentage of the charge can be sintered as above stated.

This material has two great advantages for blast-furnace purposes. It is lumpy and irregular to the last degree; therefore, it is impossible for it to penetrate through the coke bed in the way that fine ore does. The particles have lost their separate identity and been merged into a homogeneous mass, and while the mass is black and, therefore, partly magnetic, it is claimed by those who have investigated that it does not consist in the main of magnetite with the irreducibility characteristic of that material.

Owing, on the other hand, to its physical and chemical composition this material does not suffer from the excessive reducibility of fine ores as above described. At the same time it is so porous and permeable to the gas that by the time it reaches the hearth of the furnace it is sufficiently deoxidized not to require extra fuel in the hearth for that purpose. Authentic figures are available which seem to indicate that an admixture of 15 to 25 per cent of this material in the furnace burden actually exercises a beneficial effect on the fuel consumption and the output.

As compared with the product of the rotary kiln this material has several advantages. If the material under treatment is to be desulphurized the greatest care is necessary with the rotary kiln not to heat the material above the softening point until the desulphurization is complete, as otherwise the small particles are stuck together into balls by the rolling of the kiln and seal up a sulphurous mass inside which no amount of roasting will desulphurize. The conditions are made more difficult by the fact that the melting temperature of the sulphides is very far below that of the oxides. Even if the

material be thoroughly desulphurized in the kiln, as it undoubtedly can be, the agglomeration takes place by the rolling action of the kiln in bringing the pasty particles together, like the rolling of a snowball down a hillside, and this process necessarily tends to hammer out, or seal up, all pores which might accidentally form in the material, which is, therefore, dense and round, as compared with the porous, rough, irregular condition of the sinter produced by the passage of the blast through it. The consequence is that material produced in the kiln when used in mixture with softer and more reducible ores exercises a distinctly unfavorable influence on the working of the furnace necessitating slower driving and higher fuel consumption. This is a matter concerning which I have had definite and positive experience.

In addition to these materials there are others, by-products of other phases of the iron industry itself, notably an iron-silicate slag produced in the manufacture of puddled iron, heating furnace cinder, the scale from ingots or blooms charged into reheating furnaces for the purpose of bringing them to the rolling temperature, and mill scale, the black magnetic oxide of iron which forms on the red hot material being rolled, and cracks off at its passage through the rolling mill. The latter is almost a pure oxide of iron which is quite free from silica, but on account of being magnetic oxide is somewhat irreducible in spite of its rather finely subdivided condition.

The first two, as stated, are fused silicates of iron, the scale in the latter case fluxing itself with materials dissolved from the brick of the furnace. These materials are produced by true fusion, and complete chemical union of the iron with the silica. Ferrous silicate is in itself a very irreducible compound, probably the most irreducible with which we have to deal, while owing to its being produced in the completely molten condition, and in the absence of any passage of blast through it the material is exceedingly dense and impenetrable to the gas, thus increasing its irreducibility. These facts were well shown by some remarkable transparent slides like geologist's rock sections prepared by Mr. G. B. Klugh, and shown at the October meeting of the Iron and Steel Institute in Chicago in 1913. From the magnified image of the section thrown on the screen the differences in the materials were very apparent, and the reason for the superiority of sintered material over fused silicates became very evident.

THE USE OF THE DIFFERENT ORES IN THE FURNACE

The varying characteristics of these different ores, natural and artificial, affects their use in the blast furnace very materially. The variations are so numerous that it is impossible to deal at length with all of them, but we may touch upon some of the more important. Perhaps the most important is the difference between the magnetite and hematite, of which the former contains materially less oxygen in proportion to the iron and, therefore, contributes a small quantity of oxygen for the oxidation of the gases in the shaft, thus cutting down the heat development in the shaft materially. On the other hand, this ore retains its oxygen more strongly than does hematite and probably carries a larger proportion of its total oxygen into the hearth, so increasing the requirements of hearth heat for its final reduction and also increasing the solution loss of coke simultaneously. The result of these two actions undoubtedly causes magnetite ores to require more fuel and a longer time in the furnace for smelting, thereby increasing both the fuel cost and fixed charges for the iron so produced, and these causes have militated against the popularity of this ore in spite of the fact that it is fre-

quently quite rich, either naturally or by magnetic concentration.

Another factor of great importance is the size of the individual ore particles. If these are lumpy so that they cannot roll down through the coke charge solution loss is diminished, while the smaller surface presented to the gas in the zone in which decomposition of CO takes place probably reduces the extent of that catalytic action, and thereby diminishes the deposition of carbon dust with the evils which it causes by obstructing the interstices of the charge and so causing high pressure and consequent slipping in this zone.

If the ore be too lumpy, that is, if the individual lumps be too large, particularly with a dense ore, their exposure to the action of the gas is insufficient and either the ore is not properly reduced when it reaches the hearth, or else more time is required for that operation. If great variations in the size of the ore occur, some being charged quite fine and other as large lumps, then the lumps are reduced much more slowly than the fines and are likely to descend unreduced into the hearth causing raw slag and other bad operating conditions.

Plenty of cases are known in which the failure

to break large lumps by the stock-house men charged with that duty has caused furnaces to work very badly, and ore should never be charged in that condition.

The evils of excessively fine ore, on the other hand, have already been pointed out. Its tendency to run ahead through the charge, its excessive catalytic action on the gas, and above all the excessive solution of coke which it causes render fine ores inherently less desirable than ores of the same analysis in a better physical condition.

It is also a matter of great importance that ores of different physical condition act very differently on the bell. The lumpy ores slide freely and with high velocity, the plastic ores, or fine ores containing alumina, slide very slowly and even build up on the bell. The consequence is they are delivered into the furnace at a much slower speed, and their position relative to the coke charge and the walls of the furnace is very different, so that a change from an ore of small lumps to one of coarse lumps in one direction, or of plastic fines in the other, all being of the same composition, would work considerable and probably serious changes in the operation of the furnace.

Flotation Symposium at Ottawa

A Report of the Papers and Discussions on Flotation at the Ottawa Meeting of the Canadian Mining Institute

The eighteenth annual meeting of the Canadian Mining Institute was held on March 1, 2 and 3 at the Chateau Laurier, Ottawa, Ontario. The proceedings were opened by the Hon. P. E. Blondin, Minister of Mines for the Dominion. The keynote of his address was that "this great world war has awakened Canadians to a realization of their country's unlimited mineral resources."

Mr. Arthur A. Cole, president-elect, in the chair, welcomed the members and guests and reiterated Mr. Blondin's remarks.

Five business sessions were held on the first two days, followed by the annual dinner. A very interesting trip on the last day was made, by courtesy of Dr. J. Bonar, deputy master, through the Royal Mint. Trips were also arranged to inspect the ore dressing and other laboratories of the Mines Department, the Museum of the Geological Survey and the National Gallery.

Mr. Arthur A. Cole, Cobalt, Ont., was elected president and Mr. Charles Fergie, Montreal, and Mr. D. B. Dowling, Toronto, vice-presidents, all by acclamation.

The two principal subjects of discussion at the meeting were the proposed new taxation of mining concerns, against which a resolution was unanimously adopted, and the flotation of ores. Of the flotation symposium we herewith give a full account. Four papers were presented in this symposium.

The Flotation Process

The first paper on the flotation process, by Mr. T. A. Rickard, which is published in full in the March issue of the *Monthly Bulletin* of the Canadian Mining Institute, pointed out that it is not yet four years since the starting of the first American mill using the frothing method of flotation, yet 55,000 tons of ore are being treated daily by this process in the United States today. This means 20,000,000 tons per annum. The larger part of these metallurgical operations began within the last two years. It is evident therefore that

the process is gaining ground so rapidly as to command the intelligent attention of all those engaged in mining.

To Ben Stanley Revett the author gives credit for having recognized as early as twenty-seven years ago that the key to the flotation process is to be found not in the oil, the acid, or the apparatus, but in the bubbles.

The man who understands the physics of a soap bubble has mastered the chief mystery of flotation. To put it briefly, the boy, having dissolved soap in water, holds a little of it in the bowl of his clay pipe while he blows through the stem. The soapy water forms a film that is distended by the boy's warm breath into a lovely sphere, which is lighter than the surrounding air and therefore rises, while the sunshine undergoes refraction into the colors of the spectrum. When the boy blows through his pipe into pure water, he makes bubbles likewise, but they break instantly. It is the soap that lengthens their life. In the language of physics we say that high "surface tension" causes the pure-water bubbles to burst immediately, while the addition of soap introduces a contaminant that lowers the tension so as to enable the bubbles to last longer. The basic factor in the making of bubbles is surface tension.

The force of surface tension has been measured by ascertaining the weight that can be suspended from a film of water in air¹. It has been stated as $3\frac{1}{4}$ grains per inch² or 81 dynes per centimeter.² The most recent determination is that of Theodore W. Richards and Leslie B. Coombs³, who found it to be 72.62 dynes per centimeter at 20 deg. C. Many disturbing factors enter into the measurement of this force, so that diverse figures, ranging from 70.6 to 81 have been announced at different times.

Surface tension differs as between various liquids

¹A Text Book of the Principles of Physics. By Alfred Daniell, 1911.

²"Soap Bubbles," by C. V. Boys.

³Clerk Maxwell in the *Encyclopedia Britannica*, under "Capillarity."

⁴The Surface Tension of Water, Alcohols, etc. *Jour. Amer. Chem. Soc.*, July, 1915.

and fluids in contact; for example, the tension separating mercury from water amounts to 418 dynes per centimeter, while that separating olive oil from air is only 36.9 dynes. A drop of pure water will spread over the surface of pure mercury as oil will spread over water. The surface tension of an oil-water surface is only 14, as compared with the 73 of an air-water surface at a temperature of 18 deg. C. While the film of oil on water may be only one molecule thick, or one twenty-five millionth of an inch, it will suffice to reduce the effective pull of the water surface from 73 to 43. This latter figure represents the effective surface tension of water modified by oil as used in flotation. It is the main factor in the formation and persistence of a bubble. Heat lowers the surface tension of water. Place powdered sulphur on the surface of the water on a horizontal plate of clean metal; apply heat locally; the sulphur is pulled away by the cold liquid as against the feeble tension of the warmer liquid.

The contractile force at the surface, whereby a portion of liquid gathers itself into spherical form, explains why the pure-water bubble bursts so readily. The high tension shatters it. It does not burst explosively, by expansion of the gas within the envelope, but by lateral displacement of the substance of the elastic film. It collapses because the surface tension draws it together. To prevent such immediate collapse it is necessary to lessen the tension; that is, diminish the contractile force in the elastic membrane constituting the film of the bubble. This can be done by introducing an impurity or contaminant, which lowers the surface tension; that is, diminishes the contractibility of the bubble-film. Water has the highest surface tension of any common liquid except mercury, so that the addition of another liquid usually lowers its surface tension.

Oil in emulsion and organic substances in solution can be used for this purpose. Soap will have the same effect, and that is why a soap bubble lasts longer than a pure-water bubble, the film of the former consisting of water having some soap in solution. When water has been modified by such a contaminant, the components of the film can so dispose themselves that the superficial forces will be the same everywhere; that is, tend to remain in equilibrium, including the force of gravity, which otherwise would pull the film apart.

When two bubbles come in contact they tend to coalesce because the two of them have an aggregate area greater than that required to include the same amount of air within a single bubble. In pure water the bubbles coalesce with a violence that is mutually destructive. Even when a survivor is left, the violence of coalescence of such bubbles in a pulp unhorses any mineral particles that may be riding the bubbles. When, however, the water is modified by oil, the contractile force of surface tension is diminished, the bubbles are less fragile, and they survive long enough to perform their metallurgic duty of buoying the metallic particles to the surface of the liquid pulp. In practice the "modification" of the water is effected by emulsification or minute sub-division (as in a mayonnaise) of an insoluble oil, such as cotton-seed and oleic; or it may be done by means of a soluble oil or derivative, such as cresol and amyl acetate.

The presence of a contaminant in water may also affect its viscosity or internal friction, whereby it offers resistance to a change of shape. This strengthens the film of a bubble generated in such water. Moreover, it has been asserted⁷ that a concentration of the contaminant occurs in the surface of a liquid, causing the viscosity to be highly magnified as compared with the body

of the liquid. It is also known that the films made of any definite liquid are of the same strength, irrespective of their thinness; so that the attenuation of the skin of a bubble does not decrease its strength. This again follows from one of the most remarkable properties of a bubble; the ability, within small limits, of adjusting its tension to the load.⁸ Briefly, the tension at the surface of a contaminated liquid is able to adjust itself within fairly wide limits. Thus a film of liquid can remain in equilibrium when a film of pure liquid⁹ would have to break.

In his book on flotation T. J. Hoover¹⁰ states how the presence of a mere trace of saponine will kill the froth in the flotation cell. He does not explain why. It happens that saponine, which can be dissolved out of horse-chestnuts, is an aid to the blowing of big bubbles. But they are weak and tender. Why? Because saponine increases the tension.¹¹

In discussing the flotation process, the author points out that we are dealing with a pulp consisting of ore and water, modified by oil, the ore having been crushed sufficiently to separate the metallic sulphides from the associated gangue in a pulp consisting of minute particles of each. In ordinary water-concentration the lower specific gravity of the gangue permits the millman to wash it away from the heavier metallic sulphides, but in the flotation process this action is reversed, the metallic particles being lifted above, and away from the gangue particles. Apparently, it is a metallurgic anomaly.

To this crushed ore we have added oil. The oil serves as a contaminant that lowers the surface tension; also it augments the viscosity of the liquid. These two effects unite in facilitating the formation of strong and persistent bubbles. The necessary air is introduced by agitation or by direct injection. Sea-weed contaminates sea-water and makes foam in the breakers, as oil makes froth in fresh water that is agitated.

Air has a marked adhesiveness for metallic surfaces: this attachment is supposed to be enhanced by the presence of oil or grease on the metallic surface. In other words, the metallic surface, such as that of a sulphide mineral, when in the presence of both oil and water, will exhibit a preference for the oil. Hence the sulphide is not wetted. This characteristic is less marked on the part of the heavy silicates, such as rhodonite or garnet; and still less evident in the case of the lighter silicious minerals such as quartz and orthoclase.¹² The addition of acid lessens the oil attachment to the gangue particles without decreasing the selectiveness of the oil and the air for the sulphide particles. Thus we can understand why the bubbles attach themselves to the metallic particles and buoy them to the top, while ignoring the gangue particles, which sink to the bottom of the vessel in which the pulp is undergoing stirring or agitation. This preference of air for metals and metallic surfaces must be emphasized. It is the decisive factor in the process of flotation.

When using the, at present, minimum quantity—say, one-third of a pound of oil per ton of ore—it would appear that the oil forms a coating of microscopic thinness upon the metallic particles. The minimum thickness is the thickness of a molecule.¹³

⁷"Thermodynamics," by Willard Gibbs. Page 313. "In a thick film, the increase of tension with the extension, which is necessary for its stability with respect to extension, is connected with an excess of soap (or some one of its components) at the surface as compared with the interior of the film."

⁸In a chemically pure liquid it is impossible to form froth or multiple bubbling. Some differentiation of the components of a liquid is required to make a film.

⁹"Concentrating Ores by Flotation," Page 99, Second Edition.

¹⁰"Soap Bubbles," by C. V. Boys. Page 115.

¹¹Kenneth A. Mickle. Proceedings of the Royal Society of Victoria, Vol. XXIV, Part 2, 1911.

¹²"Oil Films on Water and on Mercury." By Henri Deveaux. *Mém. d. Sci. Press.* July 31, 1915, page 156.

⁶A Text-book of Physics. Poynting and J. J. Thomson, 1913.

⁶Samuel S. Sadtler in Minerals Separation v. Miami case, 1915.

Metallic surfaces have a selective adhesion for air and for oil, as we have seen. Therefore the molecular forces of the oil and of the metallic surface may be supposed to unite in attracting the bubbles. What the nature of those forces may be is yet a matter of conjecture, although the idea that they are electrostatic is suggested by the fact, among others, that the metallic sulphides most amenable to flotation are good conductors of electricity.¹³

The foregoing statement of physical principles applies more particularly to the frothing method. In true bulk-oil flotation, which, as a matter of fact, was rarely performed, the phenomenon of surface tension does not play a prominent part. It is mainly a question of raising a mineral heavier than water by aid of a liquid lighter than, and not soluble in, water. The emulsification of the oil was carefully avoided by Elmore. In the later phases of flotation, in which the proportion of oil becomes steadily less, it is aimed to emulsify the oil and air. The oil produces a "micro-emulsion of air," as Leverrier expressed it. Thus the air is thoroughly distributed in the pulp and the oil is brought into intimate mixture with the water, which is thereby modified and prepared for the making of persistent bubbles.

The author then gives a concise statement, with illustrations, of the different flotation processes which are all more or less well known (Bradford, Macquisten, Wood, Totter, Delprat, De Bavay, Elmore, Cattermole, Minerals Separation, etc.). From this summary the author concludes it is clear that three processes are covered by the general term "flotation," and that to clarify the discussion of the subject it will be well to distinguish between

1. Film-suspension, as in the Wood and Macquisten methods.

2. Oil-flotation, as in the Robson and Elmore bulk-oil methods.

3. Bubble-levitation, as in the Elmore vacuum, Delprat, Froment and Sulman-Picard methods.

The third class can be further sub-divided according as carbon dioxide or air is the principal gas utilized for making bubbles. Finally, the air-bubble methods can be classified according to the way in which the air is introduced:

- (1) From the bottom of the vessel, as in the Callow and Owen cells.

- (2) By being entrained or dragged into the pulp by the beating of paddles or some other form of impeller, as in the Gabbett and Hoover mixers.

- (3) By escape from solution in water, as in the Elmore vacuum machine and the Norris apparatus.

It remains to emphasize the fact that from the high ratio of 3 tons of oil per ton of ore the proportion of oil used in flotation has decreased, by reason of the recognition of the part played by air, to one-third of a pound per ton of ore; that is 1/18,000 of the quantity used by Robson. Concurrently the acid used has decreased to a minus quantity, namely, alkalinity.

The author then gives a concise summary and analysis of the patents on the flotation process and finally concludes as follows:

For the most part, until quite recently, the information available on the flotation process had come from patentees, their friends, and their enemies; a good many of the facts available have been elicited in the course of litigation, which has now been in progress for ten years; therefore a vast amount of non-science has been mixed with the little science that has survived amid thoroughly uncongenial surround-

ings. Anybody familiar with the bitter business feuds and personal vendettas generated during the course of the quarrels over patent rights needs not to be told that keen prejudice, amounting in some cases to malice, has been injected into the ragged literature of flotation. The warping of scientific vision is astounding to the detached observer. Much that has got into print and more that has escaped a permanent record has been written with a jaundiced eye on the law courts. On top of this the metallurgy of the subject has been placed under an embargo of secrecy by the owners of the chief patents, and this has been effective to the extent of preventing the technical men in the employ of the process-mongers from contributing to current knowledge. Only recently has there been any considerable contribution from independent sources of information.

Another important element in retarding the technology of the process is the ignoring of the fact that it depends far more on physical than on chemical considerations. *To the physicist, not the chemist, we must look for guidance.* The metallurgist hitherto has depended upon chemistry to guide him; he must now go back to school and acquire something more than a smattering of physics, if he expects to understand the problems of the new process. To most of us chemistry comes more easily because it has a sign language, that of the formula, to convey ideas, while physics depends upon the use of terms, half of which beg the question. Hence the student must begin by rejecting the use of terms that he does not understand, and when he has learned to understand them he must take pains to define them whenever he undertakes to convey his ideas to others. By such sincerity of thought it will be possible to make real progress, and to apply science to industry with results far transcending any hitherto achieved in this field of human activity.

Discussion

Mr. G. D. Van Arsdale, New York, opened the discussion with the following remarks:

"Mr. Rickard's paper is extremely interesting and comprehensive, covering as it does the history, practical development, theory, patents and some of the litigation of flotation.

"The work which I have been doing has until recently been confined entirely to an attempt at an investigation of the theory of the subject, so that I can only comment on that portion of the paper relating to this.

"Any part of this subject is very complicated and difficult from a research standpoint, and it seems to me, therefore, that its study may be facilitated by making, when possible, some simplifying assumptions.

"The most prominent feature of our modern methods is the foam or froth. Let us consider what a foam or froth really is. A scientific definition would be a matter of some difficulty, but for practical purposes we can consider that a foam or froth is really only a collection of bubbles of greater or less size or number.

"We can, accordingly, simplify matters greatly by considering a single bubble. Now a single bubble may be very roughly defined as a surface of liquid in contact with or in some cases entirely surrounding a quantity of gas. With this definition we can make a still further simplification which is that what we ordinarily call a liquid surface answers to a part of this definition; that is to say, it is a liquid surface in contact with a gas, and we would accordingly expect a study of particles and oils on an ordinary surface to throw considerable light on the remaining much more complicated cases of practical flotation.

¹³"The Electrical Theory of Flotation." By Thomas M. Bains, Jr., *Min & Sci. Press*, Nov. 27 and Dec. 11, 1915.

"If, then, we ask why does a particle, heavier than water, float on a water surface we can attempt to answer this as follows:

"If the main cause is surface tension, there should be a definite relation capable of experimental verification between the maximum size of a particle that can float and the surface tension of the surface. It has been stated that the maximum weight that can be supported on a surface is equal to the surface tension, that is, 1 sq. cm. will support 81 mm. It can easily be shown, however, that 1 sq. cm. will support several times this weight, so that evidently the relation is not as stated.

"From certain surface tension formulae, however, we can calculate the maximum-sized particle of certain shapes—for example, cylinders, that will float, and experimentally, for example, with clean copper wire of various sizes, the actual size that will float is very close to this theoretical maximum.

"This proves absolutely, therefore, that we are correct in assuming surface tension as one of our main causes. Other conditions, all of which can be proved experimentally by simple experiments are:

1. Size and specific gravity of particle.
2. Shape of particle.
3. Inherent quality of surface to resist wetting.
4. Films.

"It is easy to show experimentally, as we also know from practice that some films prevent and others promote flotation, also that these films may be either a solid, a liquid or a gas or an electric film; that is to say, an electrostatic charge.

"Now summing up the above, we can state that a substance specifically heavier than water may be made to float, provided the size of particle be small enough, or proper shape, with respect to size and specific gravity, and provided it has a surface film sufficient to prevent wetting, which film may be either a solid, a liquid, a gas or an electrostatic charge or a combination of these.

You at once see that this statement is very close to a similar statement as to the conditions producing colloids, and the study of colloids as applied to flotation will, therefore, doubtless clear up the subject considerably.

"The main conclusion we have reached in the application of the above to the more complicated cases of actual flotation practice is that surface tensions and the resultant of these which determine wetness or non-wetness of particles is the 'how' of flotation or, in other words, the immediate cause or mechanism of the results, and that the study of the colloids and electrostatics will furnish the 'why' or the ultimate cause. Electrostatics will very probably act as one of the explanations of wetness or non-wetness, and also possibly as one of the explanations for the attachment of films.

"The study of flotation oils at first glance also seems hopeless in view of the number of these and the number of possible combinations, but we can also simplify this very much if we consider them from the standpoint of their functions.

"Their main functions are evidently two:

1. To furnish a non-wet film on the particle.
2. To furnish a froth by reducing the surface tension.

"This at once gives us a classification of oils into two kinds with respect to these functions:

1. Oilers.
2. Foamers.

"By taking into account also the interaction of physical qualities of one or the other in a mixture, we can have a somewhat rational basis for this study.

"What we apparently have not so far obtained and need very much is a definite understanding and statement of the specific physical qualities of the oils themselves which they need to enable them to fulfil these functions and, as a result of this, a rational and scientific method of testing for their selection and use."

During the following discussion Mr. H. W. Du Bois, Philadelphia, pointed out that the phenomena of flotation are apparently so simple that the "reason for" has been lost sight of. The art has been developed much more rapidly than the theory.

Dr. A. Stansfield, McGill University, brought forth a burst of applause by saying that in considering a study of soap bubbles and their relation to flotation he could not rid himself of the idea that "the reason soap bubbles stick together is because of the stickiness of them."

Flotation of Bornite

Mr. H. W. Du Bois, Philadelphia, Pa., presented the second paper of the symposium, dealing with the flotation of bornite.

In Hoover's book it is stated that it is impossible to treat by flotation ores containing a chalcocite or bornite. Mr. Du Bois pointed out that this was an error, for chalcocite is easily floatable. Bornite, however, is quite another "nut" to crack. Bornite is always accompanied by a surface film ordinarily considered now to be "limonite," and this prevents the oil from coming into contact with the mineral particle.

In an attempt to overcome the film effect on their oxidized ores, the Braden Copper Company started introducing the oil during the crushing period, so that a more intimate contact was obtained while the mineral surfaces were fresh. They found that it was possible to greatly increase the recovery in this way on all ores containing oxides or minerals with drusy surfaces, but recovery is by no means good even yet.

When the feed is low grade the loss due to the content of bornite is not important, but when high, as it is in the Alaskan field (sometimes 20 per cent), it is most important.

The first attempt to overcome the effect of this "limonite film" on the Alaskan bornite ores was a repetition of Braden's more or less successful work—that is, by means of fine crushing, but this was a failure. It is, of course, possible to remove this "film" by using sulphuric acid, but in an isolated field like Alaska the high cost of acid makes its use prohibitive.

The difficulty of the problem led to a closer study of the "reason for" flotation, and the electrostatic theory seems to be the best explanation of the problem.

Assuming this theory to be correct, then we can say that in flotation we have a system in which the mineral particles are positively charged and the gangue negatively. The oil particles are negatively charged, and so adhere to or "wet" the mineral particles and repel or do not "wet" the gangue particles. If then we consider that for some reason bornite is negatively charged, we have at once an adequate explanation of the fact that bornite has been unfloatable.

Some work has been done along this line, and it has been found that by treating bornite to the fuming action of nitric acid, it is then readily floatable. This is simply a change of polarity due to high temperature, the negatively charged bornite becomes positively charged and is immediately "wetted" by the oil and floats. It is hoped that a further study along lines suggested by the electrostatic theory will yield very important commercial results.

Mr. Du Bois stated that a number of companies control the feed to the flotation unit and keep it low in

order to get high extraction. This possibly is correct, but their experience with high-grade ores has been that this is entirely unnecessary.

Recent Improvements in Conditions at the Washoe Reduction Works, Anaconda, Mont.

The next paper in the flotation symposium program dealt with the flotation equipment at Anaconda, Mont., the author being Mr. E. P. Mathewson, Anaconda.

On Jan. 25, 1916, the last section of the remodeled concentrator of the Washoe Reduction Works, Anaconda, Mont., was placed in commission.

Water concentration has been retained for everything above 2 mm. in diameter, this being the maximum size of material sent to Hardinge mills for grinding, the product of Hardinge mills being treated by the Mineral Separation Company's flotation process.

The concentrator consists of eight sections, each having a capacity of 2000 tons of feed daily, or allowing for repairs, etc., a total average capacity for the entire mill of 15,000 tons.

In the crushing department, there is no essential change, and the Harz jigs and upper tier of Evans jigs are as before. The two lower tiers of Evans jigs have been taken out and one set of 18 Wilfley tables, with Butchart riffles, substituted. These tables are roughers, and here ends the water concentration.

Next come the Hardinge mills, which replace the Huntington, but grind much finer. The discharge of the Hardinge mills goes to three Mineral Separation Company's machines in each section, while the slime from the upper part of the mill removed on the overflow of Anaconda classifiers is treated in a fourth Mineral Separation Company's machine after being thickened to 16 per cent solids in 28-ft. Dorr thickener. The remainder of the slime with 1000 tons daily from an old deposit is treated in a special slimes flotation building, fitted up with twenty Mineral Separation Company's machines. The concentrates from all the Mineral Separation Company's machines is transferred by launders and elevators to 50 x 12-ft. Dorr thickeners and hence to Oliver filters. The overflow of the Dorr is sent to large settling ponds to recover any values in froth that may not have settled out in the same.

The average grade of the feed to the mill is 3 per cent Cu. Twenty-five per cent of the feed is removed in the upper part of the mill in the form of concentrates by water concentration; 11.50 per cent is recovered as concentrates from the flotation machines. The average tailings (slime and sand) run 0.15 per cent Cu. This, after allowing for loss in overflow and leakage, gives a net recovery in form of concentrates of 96 per cent of the Cu. in the original ore.

The tailings from the flotation machines have been found to be quite suitable for the manufacture of building brick and a plant with a capacity of 17,000 bricks daily is now operating on this material.

The equipment for each of seven sections of the concentrator is as follows:

- 1—12 x 24-in. Blake crusher.
- 2—8 x 20-in. Blake crushers.
- 6—Coarse concentrate Harz jigs.
- 6— $\frac{3}{8}$ -in. concentrate Evans jigs.
- 12—Fine concentrate Evans jigs.
- 4—Sets of 55 x 24-in. rolls.
- 18—Wilfley tables—Butchart riffles.
- 8—8-ft. Anaconda classifiers.
- 6— $7\frac{1}{2}$ x 72-in. Hardinge mills with individual 225-hp. motors and using steel lining and steel balls.
- 6—Dorr simplex classifiers inclosed circuit with Hardinge mills.

4—Mineral Separation Company's flotation machines having 15 agitators and 14 spitzkastens each, and individual 150-hp. motors.

The necessary elevators, trommels and dewatering tanks.

Section No. 1 has four fine concentrate Hancock jigs, instead of Evans jigs, and uses 8-ft. x 12-ft. tube mills instead of Hardinge mills, the balance practically as stated above.

The product of water concentration is drained in suitable tanks and then transferred in cars to the smelters.

The concentrates from the Mineral Separation Company's machines are thickened in Dorr thickeners—50 ft. in diameter and 12 ft. in depth—and the thickened material is filtered in Oliver filters, from which it is conveyed on belts to the roasting plant. The tailings are sluiced to the dump by waste water from the mill.

The horsepower required per ton of ore is 0.96, divided as follows:

	Hp.
Feeding and coarse crushing.....	125
Roll crushing.....	220
Jigging.....	60
Screening.....	37
Conveying and elevating.....	237
Table concentration.....	25
Pine grinding.....	655
Flotation of sands and slimes in mill.....	426
Dewatering mill slime pulp.....	3
Flotation of slime in slime division.....	109
Dewatering flotation concentrate.....	25
Sampling and assaying.....	1
Total hp.,	1923
Tonnage daily,	2000
Per ton,	0.96

DESCRIPTION OF MINERAL SEPARATION COMPANY'S FLotation MACHINE, AS INSTALLED IN CONCENTRATOR AT WASHOE REDUCTION WORKS

The feed is introduced into the first agitator box at the motor end of the machine. From this box it passes to the second box through an opening in the partition. From this second agitating compartment the pulp passes into the first spitzkasten, where the first concentrate froth is removed by means of a paddle, and the remaining pulp passes through a pipe—the inlet to which is controlled by valve to the third agitating box from this on down through the machine until the pulp is introduced into the fourteenth spitzkasten. The discharge from the fourteenth, or last spitzkasten, leaves the machine as tailing. The first four to seven spitzkastens make a finished concentrate, and the remaining spitzkastens make a middling which is returned to the system.

The drawing (not reproduced here) shows a double machine, each machine, however, being run as a separate unit. The line shaft is driven by a 150-hp. motor at a speed of 385 r.p.m. The machine under load requires about 100 hp. The vertical shaft carrying the impellers revolves at a speed of 223 r.p.m.

The impellers are the usual Mineral Separation Company's type, having four blades placed at 45 deg. to the vertical. The impellers are 2 ft. in diameter. Each pair of impellers is arranged so that one impeller revolves in one direction and the other revolves in the opposite direction—this tends to balance the side thrust of the line shaft. The bevel gears which drive the impeller shafts are cut steel gears and run in grease. The impeller shaft is supported both vertically and horizontally by ball-bearings.

Some of these machines have now been in operation for very nearly a year, and thus far it has not been found necessary to change any of the gears.

It has been found of advantage in some cases to place a motor on the other end of the machine if it is necessary to heat the pulp above 100 deg. Fahr. There is

more or less steam arising from the pulp, especially at the feed end which condenses on the motors, and by placing the motor at discharge end this trouble is practically eliminated.

Mr. H. W. Du Bois, in discussing this paper, wanted to know "why Anaconda was reverting to heated solutions and the use of acid which more recent practice has been trying to eliminate." Their use suggested to him that possibly they were up against the "bornite problem," just as his company has been.

Concentration of Canadian Molybdenite Ores

The last paper of the flotation symposium related to the concentration of Canadian molybdenite ores, the author being Mr. Harry E. Wood, of Denver, Colo. The author has tested a large variety of molybdenite ores from the United States and Canada, and shipped fifteen tons of concentrates from his mill in Denver, Col., in 1915. He states that the few hundred tons now annually consumed have been derived chiefly from the hand-sorting of the crystals or scales and flakes, and from hand-screening work. Consumers have been accustomed to purchase hand-sorted ore generally negotiated on the basis of 90 per cent MoS_2 . He describes concentration by flotation in the Wood machine (a description of which was given in our issue of March, 1912, p. 132). The mechanically recovered concentrate averages 70 to 75 per cent and brings in most cases as high a price per unit as the higher percentage concentrate. The shortage of tungsten has stimulated the use of molybdenum as a substitute, and at present the price of molybdenum is four times normal as compared with a ten times increase in the price of tungsten.

The author visited a number of molybdenite mines in British Columbia and Ontario and tested samples from Quebec and Newfoundland. The fine but distinct crystals that are uniformly distributed throughout the gangue can be treated by flotation better than an ore containing large and irregularly distributed crystals, and sometimes consumers specify a 20-mesh product so that grinding of large crystals is necessary. When the ore is crushed before treatment the treatment and equipment are simplified. Experiments have shown that the ore should be crushed, and not ground or pulverized. For crushing, either rolls or ball mills are recommended. The use of ball mills is preferred, as with the use of rolls there is a tendency to roll up the semi-malleable flakes or to shape them so that they do not present a suitable area for flotation. The removal of large scales by screens or trommels is recommended, but the scales should be recrushed and floated. The ore is fed to the flotation machine directly without any sizing, if it has been crushed to 20, 30 or 40 mesh.

It is sometimes necessary to retreat the flotation products to remove iron, mica, etc. A Wetherhill magnetic separator has been used for this purpose. For recleaning concentrates a Wilfley table is of great assistance. When the gangue is a hard quartz the treatment is easy, but when chalcopyrite is present it floats with the molybdenite. The concentrate is in this case dried and refloats, the copper sulphide sinking, due to slight oxidation. The presence of graphite is not detrimental, although it is apt to be taken for molybdenite. Mica only affects the grade of the concentrate. Canadian molybdenite ores occur in a wide variety of sulphides and other minerals, and offer a complex problem for separation, but the characteristics of molybdenite are such that it can be separated if properly investigated.

Flow sheets for treatment and the results of preliminary tests and commercial operations are included in the paper.

Flotation Concentration at Anaconda

Among the important papers that have been announced for the Arizona meeting of the American Institute of Mining Engineers next September is that of Frederick Laist and Albert E. Wiggin, respectively metallurgical manager and superintendent of concentration for the Anaconda Copper Mining Co. The authors relate in detail the experiments conducted at Anaconda in flotation concentration, give a description of the remodeled concentrator as adapted to flotation, and also describe the new slime-flotation plant. From advance proofs of the paper we abstract some essential data.

The machines tested were of the following types: Standard Minerals Separation, Callow pneumatic, Froment, Towne, Fields, Anaconda and Minerals Separation sub-aeration. A large variety of oils was tested. The pulps treated were round-table feed and tailing, and current mill tailing. Round-table feed is the total slime from the mill, containing about 35 per cent colloidal solids, with about 90 to 95 per cent of total solids finer than 200-mesh. It assays from 2.3 to 2.6 per cent copper. The mill tailing is the total discard from the mill exclusive of the slime. It is all finer than 2 mm. and about 90 to 95 per cent will remain on 0.25 mm. It assays about 0.6 per cent copper.

In preliminary tests many reagents were used, with the result that it was conclusively proved that the best combination was sludge acid, wood creosote, stove oil and sulphuric acid. Fortunately these happened to be the cheapest of all reagents tested. Stove oil has since been omitted, but sulphuric acid was found of decided advantage in the treatment of slime.

Tests with Standard Minerals Separation Machine

Treatment of Round-Table Feed and Tailing.—

From a series of tests under varying conditions as to temperature, density, reagents, etc., the following conclusions were reached:

1. The economic capacity of the M. S. No. 1 machine when treating slime as produced from the mill at present (May 1, 1915) seems to be from 80 to 90 tons.

2. The best combination of reagents for the treatment of slime seems to be sulphuric acid, kerosene sludge acid, wood creosote and stove oil. There is some question as to the real value of the stove oil. Its principal function seems to be to make a more compact froth.

3. It would not be economical to retain the round tables as the recovery by treating the slime directly by flotation is just as high as by retaining the round tables and treating the round-table tailing by flotation. The grade of concentrate would probably be the same in either case, but any difference would be in favor of treating the round-table feed directly by flotation. The heating of the round-table tailing pulp, on account of its low density, would increase the cost of the flotation.

4. In treating the round-table feed directly by flotation, the resulting tailing should assay 0.30 per cent Cu, or less, with a concentrate carrying not over 40 per cent insoluble. Possibly the concentrate can be made much cleaner with no sacrifice in the recovery.

5. It is thought that the best circuit density for the slime pulp for flotation treatment is about 12 per cent solids.

6. It is thought that about 70 deg. Fahr. will be found to be the most economical temperature at which to keep the pulp.

7. Acid seems to be absolutely essential to the successful treatment by flotation of our slime.

8. The addition of air in the last spitzkasten is of no advantage.

9. Any considerable increase in speed of the agitators above a peripheral speed of about 1300 ft. per minute seems to be disadvantageous.

Treatment of Mill Tailing after Grinding through 60-Mesh.—Dewatered tailing was crushed in either a Hardinge or tube-mill operated in closed circuit with a Dorr classifier. At first no sulphuric acid was added and the pulp was not heated. It was found advantageous, however, to use acid in addition to the 50 or 60 per cent contained in the sludge acid kerosene. It seemed also to be of advantage to add the oil ahead of the grinding mill, using that as an agitator. Difficulties developed, however, due to corrosion by the acid and the small amount of copper sulphate formed. From the numerous tests conducted along this line the following conclusions resulted:

1. Although not definitely demonstrated, it is thought that the economical capacity of the M. S. No. 1 machine when treating sand tailing crushed through 60 mesh is about 175 to 200 tons per 24 hr.

2. The best combination of reagents seems to be sludge acid kerosene and sulphuric acid. However, a mixture of creosote, turpentine and pine oil, in a non-acid circuit gave good results also. The non-acid circuit, however, seems to require more delicate adjustment and more careful attendance than the acid circuit.

3. The grinding mill makes an ideal agitator, and it is of decided advantage to add the oil ahead of the grinders.

4. The treatment of the mill sand tailing ground through 60 mesh should result in a tailing assaying not over 0.10 per cent Cu and a concentrate carrying not over 30 per cent insoluble.

5. It is thought that the best density of pulp is from 25 to 30 per cent solids.

6. Heating of the pulp to about 70 deg. Fahr. seems to be of advantage, although there is a possibility that this heating may be dispensed with during the summer months without any injurious results.

7. Acid seems to be beneficial, but it is not of as much importance as in the treatment of the slime.

From tests on the treatment of a mixture of round-table feed and mill tailing after grinding through 60-mesh, it was decided that it is better to treat each separately.

Tests with the sub-aeration Minerals Separation machine were not satisfactory.

Tests with Callow Pneumatic Machine

The equipment consisted of five standard Callow cells, 2 ft. by 8 ft., a Pachuca tank for mixing, and blower and sand pumps. Power readings on the blower gave the following results:

Air Pressure, Pounds	Input to Motor, Hp.	Shafting, Hp.	Net to Blower,* Hp.
4	25.8	8.8	17.0
5	35.4	8.8	26.6
6	47.4	8.8	38.6

* Includes motor loss.

Treatment of Round-Table Feed and Tailing.—As a result of several tests using both air agitation and mechanical agitation, the following conclusions were reached:

1. On our slime, air agitation is not as satisfactory as mechanical.

2. The capacity of one standard Callow cell is about 15 to 20 tons of slime per day.

3. The Callow machine produces a clean concentrate but does not give as clean a tailing as the Minerals Separation machine.

4. The Callow machine is more sensitive and requires closer attention than the Minerals Separation machine.

5. The cost of repairs would probably be less on the Callow machine than on the Minerals Separation machine. This cost, however, is comparatively small for either machine.

6. The power required per ton treated in the Callow system is just about the same as that required in the Minerals Separation machine.

Treatment of Mill Tailing after Grinding through 60-Mesh.—In the preliminary tests it was found that the mechanical agitators were not needed, sufficient agitation being given in the grinding mill. Sludge acid kerosene was the only oil used, and was added ahead of the grinding machine. Sulphuric acid was added ahead of the flotation cells. The tailing for the period averaged 0.1 per cent copper and the concentrate carried an average of 42.2 per cent insoluble. In this preliminary period the pulp was heated ahead of the flotation cells.

In subsequent periods various modifications of treatment were tried, using acid and neutral solutions and different oil mixtures. The conclusions reached are as follows:

1. The capacity of the standard Callow cell when treating ground mill tailing is about 75 tons per day.

2. No other agitation is required if the reagents can be added ahead of the grinding mill.

3. The use of acid seems to be of considerable advantage.

4. On account of utilizing the grinding mill as an agitator the Callow machine requires less power than the Minerals Separation machine.

5. The Callow machine is more sensitive and requires more attention than the Minerals Separation machine.

The work of the Froment and Towne, and the Fields flotation machines, was found to be unsatisfactory; that on the Anaconda cell was of short duration, no definite results being obtained.

The final conclusions drawn from all tests were that the Minerals Separation machine was best adapted to the flotation work at Anaconda, and that the most efficient reagents would be sludge acid kerosene, wood creosote and sulphuric acid.

Remodeled Concentrator Adapted to Flotation

The Anaconda concentrator as remodeled for flotation consists of eight units, each of 2000 tons capacity per day. All are alike with the exception of section 1, in which Hancock jigs are used instead of Evans jigs, and tube-mills in place of Hardinge mills. A flow-sheet of the remodeled plants is given in Fig. 1 (p. 330).

The flotation division consists of four Minerals Separation machines, each having fifteen agitators 3 ft. square, and fourteen spitzkästen or floating compartments. The agitators for the Minerals Separation machines are of gun metal and are driven by bevel gears from a line shaft, the direction of rotation of the agitators alternating.

The machines are made of California red wood; the agitator boxes are further lined with hard maple extending about 18 in. from the bottom of the box.

Each machine has an individual drive, power being supplied to the line shaft by a 150-hp. motor running at 385 r.p.m. The speed of the agitators is 225 r.p.m., and as the impellers are 18 in. in diameter the peripheral speed is about 1060 ft. per minute.

Each machine makes three products, a concentrate, which goes to the dewatering division, a middling which is returned to the head of the machine, and a

Description of Slime-Flotation Plant

Because of lack of space in the mill an auxiliary plant had to be installed to handle the extra slime. This plant consists of 20 Minerals Separation machines of the same type and size as those used in the concentrator, and five 50 by 12-ft. Dorr tanks for de-watering the concentrate. The plant is designed to treat about 2000 tons of current slime and 1000 tons of pond slime.

What this plant may be expected to do, so far as the treatment of current slime is concerned, may be judged from the results obtained in the experimental slime machine, which has been operating regularly for more than a year.

The following table gives the analysis of the current slime and the assay of the composite tailing sample for the month of June. These are typical of the results which may be expected in the large plant.

OPERATION OF EXPERIMENTAL SLIME-FLOTATION PLANT

	Feed			
	Per Cent.	(Current Slime)	Tailing	Concentrate
Cu	2.10	0.27	12.0	
SiO ₂	61.00	67.70	20.0	
FeO	4.10	2.70	28.0	
S	4.40	1.10		
Al ₂ O ₃	19.00	18.30		
CaO	0.60	0.70		
Ag ⁺	1.80	0.20		
Au ⁺	0.005	0.001		

⁺ Ounce per ton.

The treatment of the pond slime offers a few more difficulties than that of the current slime. This slime has been exposed to the weather for a number of years so that the copper is partially oxidized, consequently that portion probably cannot be floated. Some results from the flotation plant at Great Falls, covering a week's operation, are tabulated below. This character of material has been treated for some time at the Great Falls plant, and the results should be a good criterion of what may be expected here in the treatment of dump slime.

OPERATION OF SLIME-FLOTATION PLANT AT GREAT FALLS

	Per Cent
Recovery based on concentrate	78.90
Recovery based on tailing	80.90
Average total Cu in tailing	0.53
Average soluble Cu in tailing	0.13
Average sulphide Cu in tailing	0.40
Average total Cu in feed	2.52

A flow-sheet of the slime-flotation plant is given in Fig. 2.

Experiments in sulphidization at Great Falls, using sodium sulphide in solution, were not satisfactory. Practically all the dissolved copper was easily sulphidized, but not all the oxidized copper was dissolved during its passage through the machine. Difficulty was found in maintaining the froth, and a large part of the natural sulphides did not float. The cause of the breaking of the froth is not clear, but may be due to impurities in the sodium sulphide.

Dewatering of flotation concentrate is done in Dorr thickeners, 50 ft. by 12 ft. The pulp is delivered to a baffle box about 5 ft. square, in the center of the tank and extending down to within a few inches of the rake arms. Surrounding this is another baffle about 15 ft. square and extending about 18 in. below the surface of the water. A water spray is used to break up froth. When treating concentrate the capacity of these tanks is from 200,000 to 250,000 gal. of pulp per 24 hr. As there is a small amount of fine material that will not settle, the overflow is run to a slime pond for future treatment. Tests with glue to aid settling did not prove satisfactory. The density of the pulp delivered to the tanks is from 18 to 20

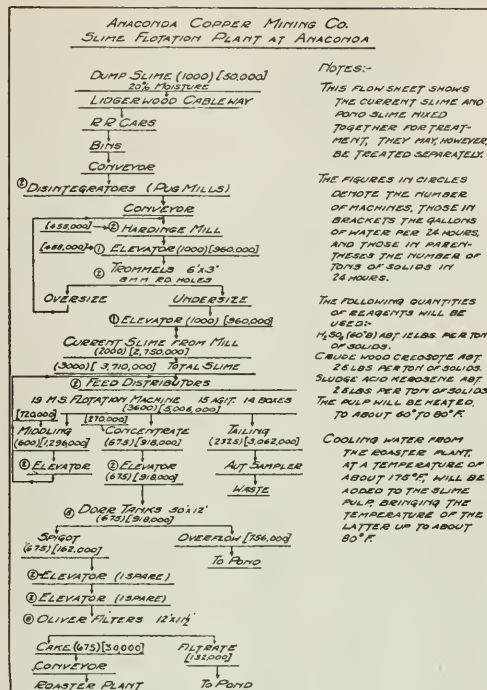


FIG. 2—FLOW SHEET OF SLIME FLOTATION PLANT AT ANACONDA, MONT.

per cent solids, and the spigot averages 60 per cent solids. The spigot product is further dewatered on Oliver filters, making a cake containing about 15 per cent moisture, which is discharged to a belt conveyor running to the roaster plant.

Meeting of the Arizona Section of the American Institute of Mining Engineers

A meeting of the Arizona Section of the American Institute of Mining Engineers was held at Globe, Ariz., on Monday and Tuesday, Feb. 21 and 22.

There were two technical sessions, in the morning and evening of Monday. Monday afternoon was spent in visiting the Old Dominion mine and reduction works. Tuesday morning a visit was paid to the International Smelter and the mine and mill of the Miami Copper Company, followed by luncheon at the Miami Copper Company's offices. Tuesday afternoon was spent in an excursion to the mine and mill of the Inspiration Consolidated Copper Company, and in the evening an informal banquet was held at the Dominion Hotel in Globe, at which there were present sixty-five members and guests of the Arizona Section. Tentative plans for the entertainment of the Institute at the Arizona meeting in September were discussed, but further development was left to the executive committee.

The following papers were presented at the technical sessions:

Co-operative Effort in Mining, by J. P. HODGSON. The author dealt with the methods employed by the Copper Queen Company in getting their men to pull together. A system of monthly meetings of the staff has been the cornerstone on which to build up the *esprit de corps*.

Shrinkage Stopping with Narrow Stopes and Pillars and Soft Ore, by J. G. FLYNN; Shrinkage Stopping with Wide Stopes and Pillars and Hard Ore, by ARCHIE SCOTT; Block Method of Top Slicing in Large Ore Bodies, by E. G. DEANE. These three papers dealt with various methods that have been used or are to be used in the mining of the ore bodies of the Miami Copper Company.

Experimental Ore Drawing Tests and the Inspiration Consolidated Copper Company's Method of Mining, by J. R. LEHMAN. This paper will probably prove to become very important as it records a laboratory method upon which are being based many of the estimates for the future operation of this big mine. A small-scale stope was filled with crushed ore and covered with crushed capping. The possible extractions of the crushed ore from such a shrinkage stope, were investigated with loading chutes spaced at various intervals along this model which was built to scale in every particular. The main conclusion is that the shorter the spacing between loading chutes and the smaller the charge withdrawn the greater the possible extraction of ore from the stope with a minimum of dilution by capping. The Inspiration Company expects to extract about 87 out of every 100 tons of ore broken and diluted with about 1.2 tons of capping. It will be interesting to see how time will bear out this prediction.

Cost and Per Cent of Saving of Ore in Selection of Mining Method, by C. E. ARNOLD. This paper, which is partly based on the results obtained with the miniature shrinkage stope, discussed the points which came up in these calculations at Inspiration.

Surface Equipment of the Inspiration Consolidated Copper Company, by H. KENYON BURCH. In this paper, which was illustrated by numerous lantern slides, the author gave a good idea of the Inspiration Concentrator which is considered the finest and most up-to-date plant of its kind. This paper was very complete and gave much very interesting detail. Everything used at this concentrator is probably unexcelled in the metallurgical field. All machinery was installed only after exhaustive preliminary tests. Even after the first design of the mill was settled on and much of the construction material ordered, new factors came up which caused the cancellation of orders and further testing. Much interest was aroused by the statement that of the original machinery planned for the first mill only the three traveling cranes are in the present mill. Everything is designed to be automatic as nearly as possible.

The Cottrell Installation at the Reduction Works of the International Smelting and Refining Co., Miami, by Dr. H. W. MORSE. This brief paper was of especial interest to the members of the section because they had an opportunity to see the Cottrell installation at the International smelter which treats the Inspiration and Miami concentrates.

Experiments on Leaching at Ajo, by Dr. H. W. MORSE and HENRY F. TOBLEMAN. After the one-ton testing plant had given very encouraging results and these had been used as a basis for the design of a large commercial copper-leaching plant, it was decided to make further experiments in a 40-ton testing plant. Much to the surprise of everyone the results did not check up those of the one-ton plant and after the rather serious difficulties encountered had been solved it became necessary to modify in some respects the ideas about the construction of the large permanent copper leaching plant now being designed for the treatment of the carbonate ores. About one-half of one per cent of the mill solution will be withdrawn on every cycle and run to waste after precipitation on scrap iron. This

will prevent fouling of the main mill solutions. The cement copper produced will be introduced into the mill circuit to reduce some ferric iron and be conveyed into the electrolytic plant. Lead anodes have been decided upon.

History of Flotation at Inspiration, by Dr. RUDOLF GAHL. The author reported what difficulties had been encountered in the operation of the 600-ton experimental flotation plant of the Inspiration Company and how they have been solved. The fruit of this large-scale test was that no new difficulties were met with when the commercial concentrator was started, the 18th (800-ton) unit of which was taken in operation during the visit of the engineers. Dr. Gahl's paper gave many details of the development of flotation at Inspiration and of the competitive tests which were made between various types of machines. The steps which led up to the development of the Inspiration machine were recounted. Some most interesting effects of the method of grinding on the flotation were detailed, especially the fact that iron filings seem to assist the flotation to a remarkable extent. A total operating cost of a little over six cents for flotation was recorded.

Grinding Practice in Miami District, by T. B. COUNSELMAN.

These papers will be further amplified and elaborated. They will then be printed and form the basis for discussions at the meetings of the whole of the Institute in Arizona this fall.

Meeting of the Montana Section of the American Institute of Mining Engineers

The annual meeting and banquet of the Montana Section of the American Institute of Mining Engineers was held on Feb. 4, at the Silver Bow Club, Butte, Mont. There were forty-nine members and guests present. Following the dinner, a business and technical session was held.

The following officers were elected for the ensuing year: Chairman, J. L. Bruce, manager of Butte & Superior Copper Co.; vice-chairman, W. C. Siderfin, manager W. A. Clark interests in Montana; secretary-treasurer, M. H. Gidel, assistant geologist A. C. M. Co. Executive committee: N. B. Braly, superintendent of mines of North Butte Mining Co. and W. T. Burns, superintendent of Electric Refining B. & M. Reduction Works, Great Falls, Mont.

Following the banquet, a paper entitled "Present Status of Oil Prospecting in Montana," was read by Prof. D. C. Bard who is joint author of the paper with Chester Steele. Mr. Frederick Laist of the Anaconda Copper Mining Company gave a talk on the metallurgy of zinc, explaining briefly the method employed by the Anaconda Company for the treatment of complex zinc ore from the Butte district.

The secretary's report shows 177 active members in the State, an increase of seventeen over that of last year.

Bibliography on Flotation.—The bulletin of the School of Mines and Metallurgy of the University of Missouri for January, 1916, contains a bibliography on flotation, compiled by Jesse Cunningham, librarian. The general references date from 1900 up to January, 1916. There is a special section on colloids and surface tension and special sections on litigation and patents. The work was originally designed for the use of students at the above university but the information should prove very helpful to those engaged in flotation work, in aiding them to avoid repetition and to compare the results of others.

Hydrogen for Military Purposes

From the very interesting paper of Captain Edward D. Ardery, Corps of Engineers, U. S. Army, presented in the symposium on electrochemical war supplies before the New York Section of the American Electrochemical Society on Feb. 11, we give the following extracts to supplement the preliminary account given in our issue of March 1 (page 260).

For military purposes hydrogen finds its greatest use in inflating balloons, either captive or free. To generate the hydrogen gas readily and in sufficient quantities, recourse has been had to various processes. Probably the first method used consisted in employing iron filings and dilute sulphuric acid. Similarly, zinc may be used instead of iron. Hydrogen from zinc and sulphuric acid is purer than when iron is used. One hundred pounds of sulphuric acid and about 140 lb. of zinc give 1000 cu. ft. of hydrogen. A balloon with a capacity of 16,000 cu. ft. would thus require about two tons of these materials.

In the Russo-Japanese war the Russians used a process based on the action of aluminium on sodium hydroxide. This method presupposes an ample water supply, and has the drawback that it requires $5\frac{1}{2}$ kg. of materials for every cubic meter of hydrogen produced. The apparatus consisted of sheet metal containers, each of which was partly filled with sodium hydroxide. The aluminium chips were held in a gauze drum, a portion of which rested in the liquid. From the producer the gas passed through the washer and from there to the balloon.

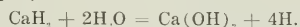
In the Morocco campaign, the Spanish government used a producer developed by Schuckert & Co. Instead of using aluminium, silicon was employed. At temperature of from 80 to 90 deg. C. the action of this element and sodium hydroxide is energetic. The temperature need not be attained by the use of fuel if the natural development of heat during the preparation of the hydroxide solution is utilized.

Schuckert's process is based on the reaction of metallic silicon and hot alkaline lye produced by the solution in water of solid caustic soda. Preparations for starting the generator consist merely in pulverized caustic soda being poured amid stirring into a solution vessel containing water, thus getting a solution of 90 deg. C. in temperature. By turning on a cock this solution is admitted to the generator, and silicon is added. During the formation of the gas, which lasts about 50 minutes, water is again filled into the solution vessel, and caustic soda in pieces added, which quickly dissolves with the aid of the hot hydrogen touching the sides of the solution vessel. This enables a new cycle to be commenced with only a few minutes' interruption at the end of every generating process. When the formation of gas is finished, the generator contains a solution of water-glass, a non-injurious liquid, which can be let out without special precaution. The heat arising does not exceed 110 deg. C. The apparatus, made of iron, and not being subject to chemical or mechanical destruction, is of practically unlimited durability.

The French have used ferro silicon instead of silicon. The producing apparatus is called "silicol." Another method originated by the French is called the "hydrogenit" process. This is particularly adapted for use where an abundance of water is not available. "Hydrogenit" is a mixture of finely powdered ferro-silicon and sodium calcium oxide. It is a gray, sandy substance, which, even in a closed receptacle, burns with a large production of hydrogen. The mixture is ignited by means of a match or a small amount of ignition powder. It comes in sheet metal containers, and is said to keep indefinitely at normal temperatures. These containers

are placed bodily in the producer and fired. The producer is surrounded by a water jacket, the contents of which are eventually converted into steam. Toward the end of the process the steam is shot into the chamber to accelerate the action. The gas is washed in water and then dried by passing through screens of sawdust and coke.

Calcium hydride, a substance known commercially as "hydrolith," (CaH_2), if dropped into water, evolves hydrogen rapidly.



The objection to it is its excessive cost. A sodium base may be used instead of calcium, but great care is necessary to prevent ignition of the hydrogen by the heat of the chemical reaction. "Hydrone" is another substance that requires only the addition of water to produce hydrogen.

A German corporation has perfected the old method of producing hydrogen by passing steam over red-hot iron filings. The steam is dissociated, the oxygen combining with the hot iron to form black oxide of iron (Fe_3O_4), leaving hydrogen free. The iron is then regenerated by blowing over the iron, hot water-gas containing a large percentage of carbon monoxide. The black oxide gives up oxygen and becomes heated. Oxygen combines with CO to make CO_2 . The process may be made continuous by using two ovens.

In manufacturing nitrogen and oxygen from the air, low temperatures are employed, but these temperatures are not low enough to effect the separation of hydrogen from water gas. Water gas consists of H, CO and N. It also contains a comparatively small percentage of CO_2 , which is first eliminated by passing the gas over caustic potash. The gas thus purified is compressed to about 30 atmospheres, and cooled to a temperature in the neighborhood of the boiling point of oxygen, say 200 deg. C. The liquefiable constituents are the CO and N, whose critical temperatures are respectively 136 and 146 C. In this process the water gas used contains about 50 per cent hydrogen, and so displays, on the whole, the physical properties of hydrogen. When allowed to escape from an open valve at the temperature of its surroundings, hydrogen does not cool, but rises in temperature. Thus the method applied in the liquification of air is not applicable for cooling water gas. Liquid air is therefore resorted to, the requisite degree of cold being obtained by allowing it to evaporate. In spite of the efforts to eliminate CO_2 and water vapor, traces of these bodies pass into the separating apparatus and are deposited there in solid form, ultimately obstructing it after the lapse of a certain time. By having duplicate plants one can be worked while the other is brought back into working shape by heating it and blowing gas through it.

The signal corps of the U. S. Army has made experiments with a view to obtaining hydrogen by refrigerating illuminating gas.

A method invented by two Dutch engineers is used both in Germany and in Russia. This process uses the gas produced by the fractional distillation of crude oil and tar. The gas is passed through a layer of hot coke, whereby the hydrocarbons break up with ultimate liberation of hydrogen. The product delivered contains from 2 to 3 per cent of CO, which is removed by subsequently treating with hot sodium oxide. Oil-gas, crude oil, petroleum by-products, tar, benzol or benzine may be employed in the same process. Charcoal can be used instead of coke. The oil is introduced as a spray at the top of the producer, having been previously heated. The coke is brought to a white heat by a hot air blast. As the oil eventually cools the coke, production is intermittent.

Our army installed a plant at Fort Omaha, Neb., for generating hydrogen by the electrolysis of water. Thirty cells were used, and 1500 amperes of direct current were passed through the cells in series. The voltage varied from 85 to 120, depending on the internal resistance of the cells.

The filter press system of Sürth came into use about eight years ago. The Sürth system is used extensively by Germany for military purposes.

Hydrogen gas from oil-gas is about 98.4 per cent pure, with a specific gravity of 0.087 to 0.092. From water gas the hydrogen is 97 to 97½ per cent pure; but if this be passed over gas soda lime the resulting gas contains as its only impurity 0.6 to 0.8 per cent of nitrogen. A percentage of 97 to 97½ hydrogen corresponds to a density of 0.094, while when the percentage of hydrogen is raised to 99.2 or 99.4, the density falls to 0.077. Schuckert's metallic silicon process gives hydrogen at least 99 per cent pure, and free of poisonous or injurious admixtures. The Sürth electrolytic process gives hydrogen 99.8 per cent pure.

Stationary plants, usually providing for generation on a large scale, must necessarily be designed along lines more economical than for portable plants. Stationary plants would find use at aeronautic establishments, army centers, and at points where gas is generated to be compressed into cylinders for shipment. Stationary plants may have capacities for generating 300 cubic meters and upwards per hour. The smaller sizes would probably weigh about 4000 kg. net, or 5500 kg. packed for ocean shipment; the larger sizes, 9500 kg. net, and 12,000 kg. gross; no piece weighing over 2000 kg. The electrolytic plant installed at Fort Omaha in 1908 had a capacity of 3000 cu. ft. per hour. To follow an army's movements portable plants are necessary. These should permit of being mounted on cars or wagons. Some plants can be set up on shipboard, some on three or fewer railroad cars and others on wagons. The capacity of portable plants varies from 9 cu. ft. per hour to 1600 cubic meters per hour.

The weights of portable plants depend, of course, on the capacity and type of plant. Schuckert's generator cars weigh about 2000 kg. each, and the scrubber cars about 1700 to 2100 kg.

In comparing the relative cost of portable plants and stationary plants distributing by means of steel tubes, consideration should be given to the cost of the tubes, their weight to be transported, and the cost of compressing the gas.

For transporting in campaign, hydrogen may be absorbed by some chemical substance dissolving it or giving with it a combination capable of restoring it easily and rapidly whenever wished; hydrolith and hydrone being in this class. Or, the gas may be compressed in steel tubes. Some French tubes are about 4 meters long, 270 millimeters interior diameter, and 9 millimeters thick. Other dimensions are used at sea and in the colonies. In order to avoid explosions, tubes have been tried with diameters of 45 to 400 mm.

The U. S. service employs cylinders about 7 ft. long, and 5½ in. in diameter; and about 4 ft. long and 8½ in. in diameter. They are made of cold-drawn seamless steel tubing.

The weight of steel cylinders is less than the weight of the iron and sulphuric acid necessary to produce an equal volume of hydrogen. The weight of these tubes does not exceed 100 lb. each. In the French service each wagon carrying tubes weighs 3000 kg. for about every 15 kg. of gas transported—about 200 times the weight of the hydrogen. They contain 200 litres of gas at 133 kg. pressure; equivalent to about 25 cu. m. at atmospheric pressure. The German flasks hold about

36 litres of gas at a pressure of 130 atmospheres, which corresponds to about 5 cu. m. of balloon space. Some American flasks contain 100 and 200 cu. ft. In some cases compression is done at from 150 to 200 atmospheres (2200 to 2940 lb.). Pressures as low as 700 lb. have been used to prevent explosion. Tanks used in welding or cutting are charged to about 100 or 150 lb. In the U. S. service the tubes are tested with hydraulic pressure up to about 5000 lb., and are charged to about one-half of the pressure used in testing. All cylinders have a safety outlet blowing at 3500 lb. The 7-ft. x 5½-in. tubes have a capacity of about 1 cu. ft., and are ordinarily charged to 120 atmospheres.

For German conditions it has apparently been found that the best method of bringing gas to the balloons is not to bring the producer to the front, but to send forward the hydrogen in steel flasks. The flasks are transported in caissons, 20 to each vehicle, and it is so arranged that six caissons can be coupled together when the balloon is to be filled. The French have some wagons that carry six tubes. The transportation of hydrogen in steel tubes is quite an old practice. The English have used tubes since 1882; the Italians, since 1887.

The Germans fill a 600-cubic meter balloon from 120 flasks in about 20 minutes. Using oil gas for producing hydrogen requires one or two hours to fire up. According to the size of the plant being used Schuckert's metallic silicon process allows of a full production of hydrogen to be reached in from 10 to 45 minutes from the time the command is given. Other processes require different periods of time before hydrogen becomes available for inflation, so the compressed gas in flasks has a considerable advantage as far as the time factor is concerned. Their two principal objections are the danger of explosion and the dead weight to be carried.

A pipe line for carrying hydrogen is in successful operation in Germany. The line is 4½ kilometers long, and can supply 1000 cu. m. of gas daily. This requires a pressure of 1000 mm. (water column.) It discharges into a storage tank. The joints of the pipe are welded autogeneously for most of the length, unions being installed at long intervals.

The cost of production of hydrogen varies, of course, with the size of the plant, market and labor conditions, and the process used. Some of the *alleged* costs per cubic meter of hydrogen, according to the process used are: ferrosilicon, 20c., hydrogenit 32c., hydrolith 100c., steam and hot iron filings 3c., distillation of crude oil and tar 3½c., water gas 25c., old method of iron and sulphuric acid 25c.; the calcium hydride method 5c. per cu. ft., silicon and caustic soda 6c. per cu. ft. By electrolysis 1500 amperes produce 23 cu. ft. of hydrogen and 11½ cu. ft. of oxygen per cell per hour.

Notes on Chemical and Metallurgical Engineering in Great Britain

(From Our London Correspondent)

The General Outlook

All prophecy is dangerous at the present time. At any time it is subject to unforeseen happenings. Today the unrealized factors may be more numerous than the cheerful optimists in Flanders imagine. At any rate they can scarcely be as dire as some distressed pessimists at home announce. So your correspondent, who resumes his letters after an interval of three months, will leave prophecy to the wise and confine his comments to actual tendencies and actual happenings. Under the latter category we are in travail with a very big distribution of labor, involving extensive re-groupings, large withdrawals of men, the initiation of un-

skilled labor, male and female, into the zealously guarded mysteries of machine minding, and the growing numbers of women employed in occupations previously regarded as purely masculine. No one pretends that the way is smooth or that minor situations do not need tactful handling. Generally we are working longer hours, and the artisan class being highly paid, there is no real pressure resulting from the high level of food prices.

Industrially we are virtually marking time in all save those industries which contribute to the equipment of the navy and the army. We cannot reasonably look at a time like the present for great mental activity, for new inventions, let alone for large outputs of commodities other than those concerned with the war. The growth of one tendency must not pass unchronicled. Month by month there is a powerful movement (destined to become still more powerful) making for a complete imperial industrial independence. Partly through an apathetic lack of imagination, partly through an obsolete—albeit economically sound—banking system, and partly through past years of laziness, we have in the past sedulously fostered an industrial dependence upon very many enemy products. Inability to barter coal, or cotton goods, or colonial produce for these during the war has indicated to us how near we were, and how ignorant we were of our nearness, to a species of industrial servitude. It is fairly certain that the movement to foster our imperial industrial independence of certain manufacturing nations will be one of the earliest modifications which we shall experience after the war. We shall, of course, have to blend the prescriptions of those who will tender their advice. Some will speak of a tariff as the magician's wand which will of itself conjure into being new highly specialized industries. Others will claim that through scientific and technical education alone our prospect of industrial success will come. Both will, of course, be important contributory forces. No wise blending of these two forces will do all we want. Psychologically, too, we must engender an industrial patriotism on which we now depend for victory.

We know now that military conflict will only be succeeded by an intense commercial warfare. The stress of competition will be much more severe than anything we have known in the past. In the present war we have forged new weapons, devised new safeguards, and regrouped very large masses of workers. New products, efficiency of output and intelligent direction are the factors on which we must depend. The most hopeful augury for the future is that we are weighing its problems and meditating on trade strategy in a way quite foreign to us in the old slothful days.

For the time, the commercial supremacy of the world will have passed to your side of the Atlantic. With it, only slightly changed in form, there will have passed all our old problems. As we regain part of our old supremacy we shall have again to meet all the old foes of our own household with new forces. Speculation, though, as to these is really too remote for contemplation to-day.

The Manufacture of Optical Glass

The movement alluded to above—i.e., that of industrial independence in Germany—is well exemplified in Dr. Rosenhain's three Cantor lectures before the Royal Society of Arts upon this subject. It was more than pleasing to be told that considerable grants had been made to the National Physical Laboratory and to other bodies for the purpose of research upon this subject.

Optical glass, Dr. Rosenhain stated, might simply be defined as better than glass, purer, and possessing vari-

ous properties for special optical purposes. The variety of purposes introduced difficulties; spectacles, telescopes, photographic lenses, etc., required different properties, apart from certain fundamental requirements. As regards transparency, the best glasses were nearly perfect. They should also be colorless, but that claim might be overdone; the greenish color due to the presence of traces of iron could be reduced by adding manganese, but at the expense of transparency, because the glass then absorbed both blue and green rays. The color was not necessarily due to impurities, moreover; certain dense flints looked yellow, especially when heated, because they absorbed the ultra-violet, and the absorption bands shifted in the hot glass. The transparency was also impeded by solid impurities (bits of clay, etc.), and by gas bubbles which were continually liberated from the carbonates and nitrates of the melting glass mixture; big bubbles carried small bubbles away, but a mist of very fine bubbles was a very troublesome feature. The fused glass finally formed a very complex solution of great viscosity and stiffness, which yet remained in a state of flow (which might become a serious matter in big telescope lenses) and inclined to crystallize. This tendency to crystallize limited the admissible properties of salts, which favored devitrification. Even a block of window glass cooled in the furnace at a very slow rate might devitrify—a specimen exhibited was full of wallastonite—and heavy barium glasses had to be chilled lest crystallization set in.

In dealing with the optical properties of various kinds of glass, Dr. Rosenhain emphasized the importance of refraction and dispersion. He said that owing to the dispersion each color gave, so to say, a different picture, and white light gave a picture with colored fringes. By combining different lenses of different glasses, achromatism could be secured, but it was only approximate and for parts of the spectrum, and a residual spectrum always remained. For the old glasses the plotting of the dispersive powers against the refractive index practically yielded a straight line. The new glasses allowed the combination of any refractive index and any dispersion. The old glasses were essentially alkali-calcium silicates (crown) or lead glasses (flint); the new glasses contained also phosphates, borates, etc., and many hitherto unused metallic oxides; their refractive index rose above 1.7, the density above 4, and barium crown glass (of high index and low dispersion) could be substituted for flint glass. A little color did not matter for gun sights and some telescopes; spherical aberration, coma, and other defects, which the Jena glasses also allowed to be corrected, were more serious.

Dr. Rosenhain's second lecture was in part historical and in part a description of different processes. The third, however, dealt with the possible improvements of the rather primitive method of optical glass making. By heroic efforts the output in this country has been raised to twenty times what it had been before the war. But that was not on business lines, and to carry the optical glass industry on after the war would require either direct or indirect state subsidy, or, better, combined research of scientists and manufacturers. The task was difficult, for Dr. Rosenhain doubted whether the optical glass industry was really profitable anywhere. At Jena, Schott and Genossen co-operated with Zeiss in instrument making and in the manufacture of chemical ware; those branches yielded the profit, while even Jena thermometer glass was being supplied at a loss, he believed. Examining the present process in detail, he pointed out that it was slow and laborious, and the yield low. To hasten the melting (which took up to four days) by higher temperatures was not advisable, if feasible. As the temperature rose, the erosion of the

pot by the glass increased. The fireclay itself would not stand more than 1800 deg. C., and the heat could only reach the mixture through the walls and the dome of the pot. The door and cover, or dome, could not be removed, because that would expose the mixture to contamination by gases (reducing gas was dangerous to flints in particular), dust, and crumbling particles dropping from the furnace arch. Electric furnaces and crucibles might be tried. Wire resistances did not yield temperatures above 1400 deg.; with spiral carbon resistance the required 1600 deg. or 1800 deg. C. might easily be obtained, but not for pots 30 in. in diameter; induction furnaces (of the Kjellin type) were unsuitable, because efficient stirring in the annular groove would hardly be possible; in arc furnaces the heat was too concentrated, though something might be done with the Stassano radiation arc, if contamination by the ash of the carbons were not too dangerous. Arc resistance furnaces (in which the arc was formed between the carbons and the slag floating on the fused metal) might answer, if something akin to the protecting slag layer could be found. It might also be possible to float the crucible on a molten, or place it in that bath of glass or slag, heating the bath by the arc resistance method. Electric glass furnaces were already used to a certain extent, but a satisfactory type had yet to be evolved.

The pot was a greater difficulty than the furnace. There was the whole group of refractory rare earths: there were silundum, carborundum and other new substances, and, lastly, tungsten and molybdenum were being put to uses not dreamed of a few years ago. Supposing they found a suitable pot material. They could then stir to complete homogeneity even near the pot walls, which they dared not do now, lest the sticky, stringy glass adhering to the walls should contaminate the bulk; they could pour the glass, get a yield of perhaps 80 per cent, instead of 20 or 30, and re-use the pot or crucible; that was the key to the problem.

The Metallurgy of Pistons for Diesel Engines

At the November meeting of the Diesel Engine Users' Association, Mr. J. M. Ferguson laid stress on the great importance of using metal of the special quality necessary for pistons of Diesel engines. Mr. P. H. Smith remarked that the fundamental cause of cracks in Diesel engine pistons was a highly heated core trying to expand but being restricted in so doing by a comparatively cold and very stiff ring of metal surrounding it. In cooling, after the engine had been shut down, the core did not quite resume its original unstrained condition. This action being progressive with alternate heating and cooling, the stresses became higher until fracture occurred. Some makers were endeavoring to find a cast iron for pistons which would not "grow" on repeated heating and cooling. Such an iron was very pure, high in manganese and low in silicon, and being mainly of Swedish origin was therefore practically unobtainable at the present time. He then described his arrangement of a renewable core in the piston head, which he considered would provide a solution to the trouble of cracking. This is made in two parts, so as to reduce stresses to a minimum in the core as well as in the piston. The core proper, or inner portion, is fixed on to a recess in the piston head by a gas-tight joint, well removed from the region of highest temperature, and is surrounded by a separate ring. The core is free to expand laterally and longitudinally, and the ring is similarly unrestricted. To reduce any tendency to crack in the remaining portion of the piston head, the recess which contains the core is stepped, the depths of the steps gradually increasing, and the top edge of the recess is sufficiently removed from the hottest region to avoid cracking or fraying out.

Synopsis of Recent Chemical and Metallurgical Literature

Gold and Silver

Segregation in Gold Bullion.—Accuracy in the assay of gold bars practically free from silver but containing base metals other than copper, as for example cyanide bullion, is the subject of a paper presented by JAMES H. HANCE, of Iowa City, Iowa, in the February *Bulletin* of the A. I. M. E. The author reports the results of an investigation begun while in the service of the Government as assistant assayer of the Salt Lake Assay Office. Variations in assays are tabulated and shown also in diagram and curves. The results are summarized as follows:

1. Drillings taken near the edge are extremely variable, but generally assay higher than the dips, a fact which may be due to early solidification and an accompanying segregation in those portions of the bar of metals of the highest freezing points, taking into account mutual solubilities and alloying tendencies. In a platinum-gold alloy this same characteristic is very apparent, but is due, as Mathey observes, to the liquidation of the platinum.

2. The center of the bar, top and bottom, is usually lower in value than the dips. As suggested in the author's paper this may be due to a late solidification in these and similar points, which results in a higher percentage of base metals with low freezing points. Mutual solubilities may be a factor here, also, but the substance in large excess (gold) does not concentrate toward the center or last place of solidification as does quartz in the cooling of a quartz-rich magma.

3. In a majority of cases the top drillings assay higher than do those of the bottom, and the same is true of the dips. In order to balance the personal equation the method of weighing assays was reversed so that the weigher who received the top samples at first, later received the bottom samples. For this reason samples were frequently exchanged in weighing. The same variations, however, continued to be apparent.

An extreme range in the dip assays is in some cases due to the presence of impurities introduced while the dips are being taken. Where a scorifier is used to catch part of the stream of metal, small pieces of clay might easily be caught and retained in the bullion granules.

4. Drillings taken at any one point along these profiles vary as widely in assay value as drillings of any other points similarly chosen. Also, maxima and minima points are as apt to occur near the center of the bar as near the ends. From this standpoint the corner drillings seem no better nor worse than drillings from nearer the center.

5. The liquation in some cyanide bars is similar to that which takes place when the rare metals are present in appreciable amounts, but in the former instance it seems to be due to the presence of certain base metals.

Attention is again called to the fact that these difficulties are not encountered where a small amount of silver is present, as the presence of this latter metal seems to diminish segregation. Lessened segregation is probably due to the solvent properties of silver toward certain base metals, such as lead, zinc, etc. Silver may exert an appreciable influence on other metals or non-metals also. Where 90 or 100 points of silver were known to be present in the bar, no dip samples were taken, and the drillings rarely failed to check well within the limits allowed. This is doubtless due to the fact that silver or silver-gold alloy in which the silver content is nearly 10 per cent or better, is a good solvent for the metals or non-metals causing segregation. Pure or silver-free gold is not a good solvent for these sub-

stances, and hence does not prevent the formation of an irregular bar.

This suggests one way of overcoming the difficulty of assaying cyanide bullion, although it does not solve the problem. If to all such cyanide bars known to contain little or no silver, a small amount of that metal be added in melting, a uniform bar after melt could easily be obtained and its fineness accurately determined. From the fineness thus obtained the inquantation silver could be subtracted, leaving the silver fineness of the original bar. As such gold bars are alloyed with silver for refining operations, the above suggested operation would mean a little additional work for the computer only, but this extra work would be more than offset by the increased accuracy of the gold assay.

Refining Cyanide Precipitate at the Liberty Bell Mill.—Owing to wide variations in composition of Liberty Bell precipitate it has been necessary to discard wet methods of refining and substitute the more exact method of flux calculation. The method is described by A. J. WERNIG, mill superintendent for the company, in a paper to be presented at the forthcoming fall meeting of the A. I. M. E. Table I gives an idea of the range in composition and grade of the precipitates.

TABLE I—RANGE OF COMPOSITION OF RAW PRECIPITATES

	Per Cent
Gold and silver	25.0 to 75
Zinc	15.0 to 30
Lead	0.5 to 52
Copper	0.5 to 20
Silica	1.0 to 5
Calcium oxide	4.0 to 8
Sulphur	0.5 to 8

The present method of flux refining has been arrived at through a vast amount of experiment. In general, it embodies the principle of the addition of an oxidizer, and the proper proportionment of fluxes to carry off the oxidized impurities as metallic bases in a fluid slag.

A rather wide experience in the melting of precipitates has shown that the various impurities of precipitates are oxidized and driven into the slag in a definite order. Zinc tends to oxidize first, and the resulting zinc oxide will combine with the acid radical of the flux and therefore enter the slag. As in blast-furnace practice, the zinc tends to render slags infusible; and for this reason borax glass is always used in a greater amount than silica to furnish the acid radical for the slag. Borax glass greatly increases the fusibility of zinky slags.

Sulphur tends to oxidize second, and if an alkaline oxide is present in the melt, alkaline sulphate is formed, which is rather easily fusible. This sulphate is not soluble in the slag, and, being lighter, rises to the surface of the melt, forming the well-known sulphate "cover." The sulphate "cover" is nearly always quite sure, so that after any melt the melter may easily separate it from the slag, and, by weighing and computing its sulphur content, obtain a close check on the analysis of the precipitate. This cover is either Na_2SO_4 or K_2SO_4 , depending on the alkaline oxide present. (The sulphate cover is an intensely interesting material to the chemist. Many unsuspected elements are known to concentrate therein. In the Liberty Bell material, Mo, As, Sb, Te, Se and V have been detected.) Where precipitate is melted without oxidizers, sulphur generally makes itself known by the formation of matte—a very undesirable by-product.

After all sulphur is oxidized, lead will oxidize, and the resulting lead oxide enters the slag proper. It is well known that lead oxide combines with silica in nearly all proportions under the influence of heat, and that the resulting lead silicates are easily fusible between rather wide limits. For this reason more silica may be used in the melt when much lead is present, and for the

same reason the amount of borax glass may be diminished.

After lead, copper will oxidize to Cu_2O and combine with the acid radical of the slag. The color of such slags is red. Where an excessive amount of oxidizer is present, copper will oxidize to CuO , and slag containing this oxide is green.

This selective oxidation is most clearly evident in the order of oxidation between copper and lead. It is practically impossible to drive copper into the slag as long as metallic lead is present in the bullion. Here quantitative separations between lead and copper are easily obtained.

Graphite crucibles have a marked reducing action on lead slags. No matter how rapid the melting, or how fast the resulting slag is removed from the crucible, if much lead is present, some will be reduced to metal. In such cases it is practically impossible, in direct melting, to slag copper, even though oxidizers are added far beyond the calculated requirement.

Where melts are conducted in clay or clay-lined graphite crucibles, this reducing action is of course avoided, and as a result copper will be found to enter the slag as easily as lead, though not until all lead is oxidized. Hence, in melting precipitate in graphite crucibles no attempt is made to slag copper. If a desirable grade of bullion can not be made unless copper is slagged, the melter will then, of course, use clay or clay-lined crucibles.

The common oxidizing fluxes are manganese dioxide, potassium and sodium nitrates. The first is costly on account of the comparatively low quantity of available oxygen. It also requires extra weight of acid flux to retain Na_2O in the slag. Sodium nitrate is highly recommended on account of its high available oxygen, and in the crude form imported from Chile it is cheap and satisfactory.

Table II gives the common impurities of the precipitate and the common fluxes. Columns 2, 3 and 4 give the weight of oxygen that the substance will evolve or combine with, in per cent of original weight of substance. Column 5 shows weight of manganese dioxide required to oxidize a unit weight of the substance on the same line in column 1. In columns 6 and 7 are given weights of nitrates required to oxidize a unit weight of substance. Columns 8 and 9 give the weight in pounds

TABLE II—FLUX TABLE

Substance	Molecular Weight	Per Cent Oxygen		1 Lb. Substance Requires, Pounds					
		Acid Base	Available	MnO_2	KNO_3	NaNO_3	K_2CO_3	Na_2CO_3	
Cu^+	63	25.4	12.7	1.40	0.07	0.91			
Cu^{++}	63	12.7		0.70	0.54	0.46			
Pb	207	7.7		0.43	0.33	0.28			
Zn	65	24.6		1.35	1.03	0.87			
Fe	56	25.5		1.57	1.20	1.01			
S	32		8	30.6	30.5	30.4	3.30	3.30	
SiO_2	60	53.4							
CaO	56		28.5						
MgO	88		15.2	18.2					
NaNO_3	85		9.4	28.2					
KNO_3	101		7.8	23.8					
Na_2CO_3	106		15.1						
K_2CO_3	128		12.5						
Na_2O	62		25.8						
K_2O	94		17.0						
$\text{Na}_2\text{B}_4\text{O}_{10}$	202	47.7	7.9						
Mixture of 2 parts borax glass and 1 part silica		49.6	5.3						39.0 per cent available acid oxygen
Mixture of 1 part borax glass and 1 part silica		51.1	3.2						44.7 per cent available acid oxygen
Mixture of 3 parts borax glass and 2 parts silica		50.0	4.8						40.4 per cent available acid oxygen
Column No.	1	2	3	4	5	6	7	8	9

of the carbonates required to form sulphates with 1 lb. of sulphur which has been oxidized to SO_2 . These carbonates are used only when MnO_2 is the sole oxidizer.

The author presents two cases of flux calculation, one of which is given in Table III. The type of slag made, two of acid oxygen to one of basic oxygen, is the result of experience. This slag is most easily fusible and least corrosive on the crucible. It runs low in precious metal, having been made repeatedly as low as \$20 per ton. While the slags vary widely in composition they all conform to the type above mentioned.

An important feature of the refining process is the sintering of the fluxed precipitate. Sintering is done in cast-iron pans in an iron muffle. The temperature is gradually raised to red heat and practically all the chemical reactions are completed. The sinter is in excellent condition for melting, giving no trouble from dusting and greatly increasing the capacity of crucibles.

Slags are stored and smelted in a small blast furnace once a year, with brick charges made from ash obtained by burning old mill launders and tanks. Considerable scrap copper also is smelted. Any matte made

in smelting precipitate is controlled by running the furnace under stronger oxidizing conditions, thus driving the metals into bullion and slag.

Copper

Grades of Coal Permissible for Reverberatory Smelting.—At the recent sessions of the second Pan-American Scientific Congress, C. R. KUZEL, metallurgist for the Anaconda Copper Mining Co., discussed coal-dust firing of reverberatory furnaces. He explained that the grade of coal that can be successfully used for this work is not fixed by close limits, and that unless there is something detrimental in the ash that would make it difficult to handle when it forms accretions in the furnaces or flues, it may be said that any good coal and many poor grades may be used. The accompanying analyses show the types of coal used at various plants.

The former classification of reverberatory coals into "long-flame" and "short-flame" coals seems to have no meaning in the combustion of coal dust in the long reverberatory furnaces of to-day, because the length of the flame can be controlled by the damper, coal feeders and burners. Physical characteristics that would make a coal unsuited for grate firing are not objectionable in the new system. Consequently it is possible to use in the form of powdered fuel a much greater variety of coal than it was possible to burn satisfactorily on grates.

The ash analyses for a few of these coals are available and are given here:

One can readily see that the ash of coals Nos. 3, 4 and 5, if agglomerated into an accretion of the composition shown, would make a sticky mass at moderately high temperatures. This is exactly what happens in the hotter part of the reverberatory-furnace flue, but the removal of these sticky masses is only a matter of minor importance. That which falls on the slag bath in the furnace is all the more easily fused into the slag

COAL USED FOR COAL-DUST FIRING

Coal Number		Proximate Analysis					Heating Value B.t.u. per lb.		Ultimate Analysis							
		Moisture	Volatiles Matter	Fixed Carbon	Ash		Dry	Wet	H ₂ O	H	C	N	Ash	O	S	
1	4.3	34.7	55.4	9.5	13,500	12,850										
2	7.0	24.5	46.3	22.1	9,910	9,210	7.0	3.8	51.7	0.6	20.3	12.3	4.3			
3	4.5	40.9	43.1	9.5	12,490	11,690	6.5	4.3	65.5	0.9	9.7	12.4	0.7			
4	10.5	39.2	42.9	7.4	13,030	12,070										
5	6.6	33.7	47.8	12.0	12,570	11,870										
6	9.0	35.5	43.4	12.7	11,500	10,590										
7	13.3	32.9	38.5	15.3	10,553	9,660										

because of this slagging tendency of the ash itself. Small additions of lime rock flux rabbled into the scum at the slag-skimming bay a few times a day is sufficient to complete the fusion. One must know the origin of the ash of coal No. 2 to understand its behavior. It is due to three things, at least: A large quantity (about 8 per cent) of "sulphur balls," which are hard, heavy concretions of iron pyrite (FeS_2); a seam of "bone" interbanded with the coal—the "bone" being carboniferous aluminum silicate which, when free from carbon, is an extremely refractory "kaolin;" and the mineral substance of the plants from which the coal was formed—in this case probably a very silicious substance. At any rate, sources Nos. 2 and 3 give to the ash a highly refractory portion of low specific gravity,

TABLE III—FLUX CALCULATION

Data and Explanatory	Pounds			
	Oxygen		NaNO ₃	Silica
	Acid	Base		
(References apply to Table II) assume 100 lb. of precipitate				
Zinc 20.5 lb.			17.90	
20.5 × 0.87 (See Col. 7, opposite Zn) =		5.04		
Lead 38.8 lb.			10.90	
38.8 × 0.28 (See Col. 7, opposite Pb) =		3.00		
38.8 × 0.077 (See Col. 3, opposite Pb) =				
CaO 2.0 lb.			0.57	
2.0 × 0.285 (See Col. 3 opposite CaO) =				
SiO ₂ 1.4 lb.				
1.4 × 0.534 (See Col. 2, opposite SiO ₂) =	0.75			
Borax Glass (as it is desirable to maintain a ratio of borax to silica of 2 to 1 in the slag it is convenient to add here the proportionate amount of borax to balance silica in the precipitate. In this case the silica is low and this correction could readily be omitted on this particular precipitate, but as it is necessary to correct for borax here when silica is high the correction for silica is carried through for form. Hence 2 × 1.4 = 2.80 lb. borax			2.80	
2.80 × 0.079 (See Col. 3, opposite Na ₂ B ₄ O ₇) =		0.22		
2.80 × 0.477 (See Col. 2, opposite Na ₂ B ₄ O ₇) =	1.34			
The total pounds of NaNO ₃ added is			(28.80)	
As this places extra basic oxygen in the slag as Na ₂ O we have: 28.80 × 0.094 (See Col. 3, opposite NaNO ₃) =		2.71		
Total acid and basic oxygen	(2.09)	(11.54)		
The 2.09 lb. acid oxygen will balance 1.2 (2.09) = 1.05 lb. base oxygen. This leaves 11.54 - 1.05 = 10.50 lb. base oxygen to be satisfied, or 21.0 lb. extra acid oxygen to be added. Using the mixture of 2 borax and 1 silica to supply this acid oxygen, we have 21 ÷ 0.39 (See Col. 10, opposite Mix. 2 B. G. to 1 SiO ₂) or 54 lb. of mixture. This is: 36 lb. borax glass			36.0	
18 lb. silica				18
also 54 × 0.496 (See Col. 2, opposite Mix. 2 B. G. to 1 SiO ₂) =	26.80			
54 × 0.053 (See Col. 3, opposite Mix. 2 B. G. to 1 SiO ₂) =		2.86		
Grand totals of acid and basic oxygen or a ratio of 2 to 1 approx.	28.89	14.50		
Sulphur—As all sulphur goes into the "cover" as well as the utter used to oxidize it we have: 1.2 - 5.30 (See Col. 7, opposite) =		6.37		
Grand totals of fluxes to be used			35.17	18.0

The melter made up the flux by parts as:

	Parts
NaNO ₃	25
Borax	39
Silica	18
Total	92

and source No. 1 gives a heavy iron sulphide of low melting point. It is very probable that the latter drops unburned into the furnace bath, because of the neutral or slightly reducing atmosphere in the furnace. The former collects on the slag and in the flue as a light fluffy deposit which has been found not to interfere at all with the calorific efficiency of the furnace.

Tungsten and Molybdenum

Tungsten and Molybdenum as Substitutes for Platinum.—In an elaborate paper in the January *Bulletin* of the American Institute of Mining Engineers, Mr. FRANK A. FAHRENWALD gives the results of an extended research on substitutes for platinum in the arts and sciences.

The substitute desired must satisfy the following conditions: Its melting point must be high, at least well above 1200 deg. C. It must not be affected by those chemical compounds formed in its application, nor should it oxidize at a soldering temperature. It must possess sufficient strength to resist stresses tending to change its form while in place, and at the same time be sufficiently pliable to be worked to the desired shape. Its coefficient of expansion must be low, in order that desired dimensions may be easily produced in the finished product. (This factor is important, since the range through which this material is manipulated is often more than 1000 deg. C.) It should unite readily with gold, silver and similar metals, and their solders. Its cost of production should be low, as compared with that of platinum.

The experimental work resolved itself into three parts, each being marked by a different method of attack, necessitated by limitations encountered as the work progressed under previously adopted methods.

The first part consisted of experiments in binary combinations of those of the metals which it was feasible to consider, and the melting points of which lay within the limits of ordinary fusion methods. The results of these experiments, performed as indicated therein, lead to the conclusion that metals or alloys of metals outside of the precious-metal groups, are unsuitable as substitutes for platinum.

The gold and silver alloys of palladium have been found to be excellent substitutes for platinum in its softer forms, and while not so chemically resistant, fill all requirements where conditions are not too rigid.

The second part develops the fact that except in two respects, pure ductile tungsten, and, to a lesser degree, molybdenum, meet all of the specifications of a practical substitute for platinum and its alloys. These two defects are its ease of oxidation, and the difficulty with which it can be soldered; and they have been overcome by coating with a precious metal or alloy, the resulting material being in many ways far superior to platinum or its alloys. This material has met with instant demand, is in many cases replacing the best platinum-iridium alloys, and permits the performance of work which has been impossible with the materials hitherto available.

The third part describes the theoretical and practical considerations involved in the manufacture of wrought tungsten and molybdenum, and gives results of the proper application of a similar method in the laboratory production of their alloys.

Wrought tungsten and molybdenum were produced on a laboratory scale, but no success attended the attempted production of alloys of tungsten with gold and palladium; while on the other hand, the alloys of the tungsten-molybdenum series were produced in wrought form. These operations were governed entirely by metallographic control, and their success suggests the

possible application of a similar method in a treatment of such metals as iridium, tantalum, rhodium, osmium, etc., in combination with each other, or with tungsten or molybdenum, which may result in the production of alloys possessing properties far superior to those of any material now available.

Recent Chemical and Metallurgical Patents

Iron and Steel

Production of Ferrosilicon in the Electric Furnace.

—A furnace for the production of ferrosilicon which is designed for the utilization of lower-grade raw materials than generally used is patented by HERBERT C. HARRISON of Niagara Falls, N. Y. (assigned to Electro Metallurgical Company of Niagara Falls, N. Y.) It is a combined combustion and electrical furnace, a cross-section of which is shown in Fig. 1. The furnace has twelve electrodes extending down into the hearth (1), as shown, the connections and adjustments needing no explanation. The roof (3) has manholes (10) with gas-tight closures (11); supported directly above the roof-opening (4) is a stack combustion chamber

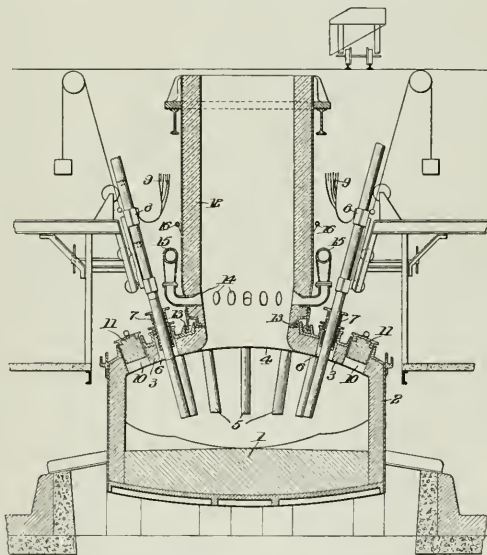


FIG. 1—FERROSILICON FURNACE

(12). Radial tuyeres connected to a bustle pipe (15) open through the lower end of the stack. The stack may be cooled by a water spray from pipe (16). The charge is made up of mill scale, intermingled with dense impermeable briquets of ground sand and coke. The carbon is slightly in excess of that required for the reduction of the silica. A charge consists of approximately 169 parts of mill scale, 269 parts sand and 139 parts coke (80 per cent carbon). The preheating of the charge is effected in the portion of the column above the tuyeres by the combustion of the carbon monoxide rising from below. The charge is introduced in the form of briquets and a temperature of about 2000 deg. C. is needed in the final zone where the silicon is reduced. Air is introduced through the tuyeres to effect combustion of the excess carbon monoxide not used in reducing iron. The process is operated continuously. (1,171,719, Feb. 15, 1916.)

Iron and Steel Direct from Ore.—A process for the production of iron and steel direct from ore by the use of fuel oil as reducing agent is patented by HERBERT HAAS of San Francisco, Cal. The process is carried out in a tilting furnace having a row of tuyere pipes on one of its sides. The tuyere pipes are also above the bath in the furnace, which consists of iron and iron oxide kept at about 1600 deg. C. Atomizers are placed in the tuyere pipes, and the oil, previously vaporized by subjecting it to a high pressure, is forced through the molten iron oxide. Firing of the furnace is not interrupted, because the heat balance shows that if proper precautions are not observed the bath will freeze, owing to the heat used to break up the hydrocarbons into carbon and hydrogen and to reduce the iron oxide. However, by limiting the amount of oil to a relatively small quantity compared with the large body of molten material it is claimed that freezing is prevented. After the iron oxides have been reduced a portion of the iron may be removed to another furnace and finished into steel. To reduce the fuel consumption and facilitate the smelting, it is desirable to maintain a bed of molten iron always in the hearth, and remove only a portion of this iron or steel, and on top of the remaining bath charge fresh iron ore and fluxes. (1,156,775, Oct. 12, 1915.)

Gas Washer.—A gas washer for blast furnace gases in which the gases are made to impinge on the surface of a series of pools of water is patented by THOMAS McDONALD, of Youngstown, Ohio. The arrangement of the washers is shown in Fig. 2. The gases enter at 2, and are first sprayed from pipes 3. They are then led down and impinge on the surface of the water in pockets 9 and 10. They then pass up and over baffle 22 and follow the course shown through the succeeding baffles. The descending spaces are made smaller than the ascending to prevent picking up of particles already deposited. The water flows from one pocket to the next in a steady stream from left to right, thus removing the scum as fast as it is formed. Bells

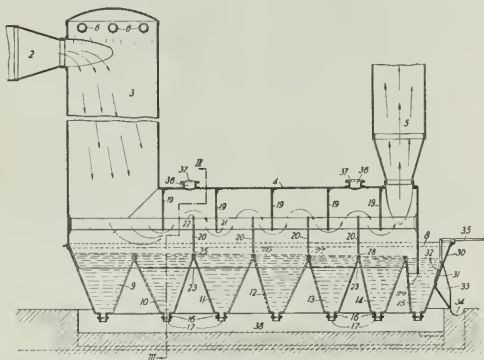
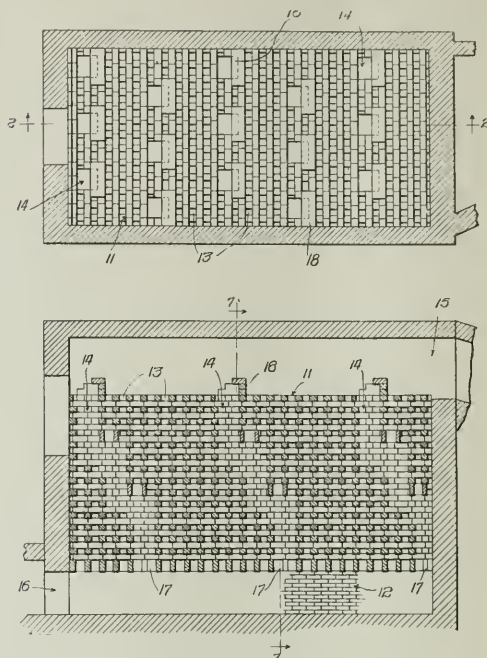


FIG. 2—GAS WASHER

16 are provided for cleaning out the pockets. The pockets are made successively smaller, as they receive less and less deposited particles as the gases pass through. (1,167,909, Jan. 11, 1916.)

Regenerator for Furnaces.—A novel scheme for constructing regenerators in order to prevent clogging up from flue dust in the gases is patented by FRANK ORTH, of Indiana Harbor, Indiana. The idea can best be explained by reference to one form of construction as shown in Figs. 3 and 4. Fig. 3 is a section-plan view, and Fig. 4 is a longitudinal cross-section of a generator constructed according to these principles. As the

gases enter at 15, they pass through ordinary sized openings 11, and larger passageways 14. Baffle plates 18 aid in a more even distribution of the gases. As the gases pass through these large passageways 14 (which are constructed sloping in the direction shown to make



FIGS. 3 AND 4—REGENERATOR CONSTRUCTION

the passageway approximately at an angle of 90 degrees with the incoming gases, whose tendency is to go forward and downward), they can find openings or longitudinal ducts on each level of brick so that there is provided a surface distribution area which is a great many times greater than if the gases simply entered at the top and went straight through to the bottom.

In practice with the old system it has been the experience that the upper sections become clogged up much quicker than the lower sections, and consequently the regenerator had to be thrown out of operation while it was cleaned. In the present method, it does not matter whether the upper layers become clogged or not as the large passageways conduct the gases down to the succeeding layers until suitable openings are encountered. The ability of the gases to pass horizontally along each layer from the large passageways is a distinct feature. The operation of the regenerator may be continued even when all the small openings are clogged, as the large passageways will still conduct the gases. The period of time before cleaning is necessary is thus very much prolonged, and a consequent saving in time and labor is effected. Many other arrangements may be made to carry out substantially the same idea, such as arranging larger intermediate longitudinal passageways, providing larger openings in the top than in the body of the regenerator, or other changes. (1,165,340, Dec. 21, 1915.)

Gaseous Reducing Agents in Iron Production.—A novel process of producing iron from iron ores by the use of gaseous reducing agents, such as hydrogen, natural gas, methane, ethylenes, or the like, in the electric furnace is patented by EMIL BRUCE PRATT, of Lake-

wood, Ohio. No special design of electric furnace is necessary. Pure hydrogen from the electrolysis of water may be used or other gaseous hydrocarbons as mentioned above. These gaseous hydrocarbons are decomposed at temperatures below the melting point of iron ore, and the process is based on the affinity of hydrogen for oxygen. It is claimed that no silicon need enter the iron if the temperature of the bath is kept even and not far above the melting point of iron, as there is no silicon in the fuel. By increasing the temperature or adding alloys, silicon may be added to the metal. No blast is necessary and finely pulverized ores may be used. It has been found desirable to pre-heat the reducing agent, especially when a hydrocarbon is used.

The claims made for the process are that it provides a means of controlling both silicon and carbon and may be used when electrical energy is cheap and solid carbon fuel expensive. (1,167,016, Jan. 4, 1916.)

Iron and Sulphur from Pyrite.—An electric furnace process of treating sulphides of iron directly for the production of iron and sulphur, is patented by Mr. LEWIS T. WRIGHT of London, England. Pyrite or other suitable sulphides of iron, either fresh material or material previously heated in some other furnace, is charged into a tilting electric melting furnace, having a single carbon electrode in the top and metallic plate electrode at the bottom. The top is closed and the sulphur vapors are conducted away through an opening in the top to a condenser. The charge is heated to about 3000 deg. C. when practically all the sulphur will distill off, leaving a bath of pure molten iron, which is tapped. Slags may also be used when desired. (1,164,049, Dec. 14, 1915.)

Copper

Hydrometallurgy of Copper.—A process for the hydrometallurgical treatment of ores is patented by ROBERT

RHEA GOODRICH of Tucson, Ariz. In this process, which is shown diagrammatically in Fig. 5, the copper solution resulting from leaching an ore is run from tank 5 to a heater 7, where it is heated to about 50 deg. C. From the heater the solution flows to electrolytic vats 11 of step No. 1. The solution is circulated through these vats by pump 13 and is returned from the last vat to heater tank 7. Part of the solution overflows from the last vat to tank 16, from which it goes to single cell 20 of step No. 2. The diagram explains the subsequent steps. The cells are all connected in series so that the same current flows through all cells. The electrodes of the separate cells are connected in parallel. The copper content of the electrolyte in the separate steps is maintained constant and in geometrical ratio, and the current density is made to correspond. For example: If the copper solution in tank 5 contains 6 per cent copper, the current may be maintained to deposit enough copper so that the electrolyte will contain 1.5 per cent copper in step 1. If the current density is 20 amp. per square foot then it is made one-fourth, one-third or one-half that amount in step 2, according to the proportion desired. In this case one-fourth was used so that one-fourth the number of cells is used in step 2 as in step 1 and one-fourth the current density. The copper content in step 2 will be made 0.375 per cent.

It is claimed that by endeavoring to maintain a constant copper content in the electrolyte through each step and maintaining this content and the depositing conditions in geometrical ratio that the conditions of ordinary electrolytic copper refining are most easily attained. (1,171,782, Feb. 15, 1916.)

Tin

Detinning Process.—A process of detinning based upon previous processes using dry chlorine has been patented by GEORGE O. SEWARD and the late FRANZ VON KÜGELGEN of East Orange, N. J. (assigned to Columbia-Knickerbocker Trust Co., New York). This is a re-issue of patent No. 851,946, April 30, 1907, and is based upon patent No. 915,029, March 9, 1909, a short description of which was given in this journal April, 1909, page 169. This latter patent aimed to treat tin scrap by placing it in a vessel and introducing dry chlorine, which attacked the tin, forming stannic chloride, which condensed on the sides of the vessel. It was necessary to control the temperature within very narrow limits, and this was done by limiting the amount of chlorine introduced and applying external cooling by water. In the original of this reissued patent it was proposed to limit the amount of tin scrap and effect temperature control in this manner. The present patent proposes to introduce a considerable excess of chlorine to carry away the excess heat generated. It is desirable to introduce the chlorine as cool as possible. With a chamber of 40 cu. ft. capacity a charge of 150 lb. of tin scrap has given successful results. (14,070 and 14,071, Feb. 15, 1916.)

Zinc

Electric Zinc Furnace.—An electric furnace for producing metals which are vaporized and condensed, such as lead and zinc, is patented by ALOIS HELFENSTEIN of Vienna, Austria-Hungary. The furnace is designed to overcome the causes of dusting such as in electric zinc furnaces, by separating the gaseous products before reduction takes place. Water and carbonic acid, also hydrogen and hydrocarbons, cause the liquid zinc to precipitate as dust (blue powder) through partial reoxidation and combination with the metal vapor. A cross-section of one style of the furnace is shown in

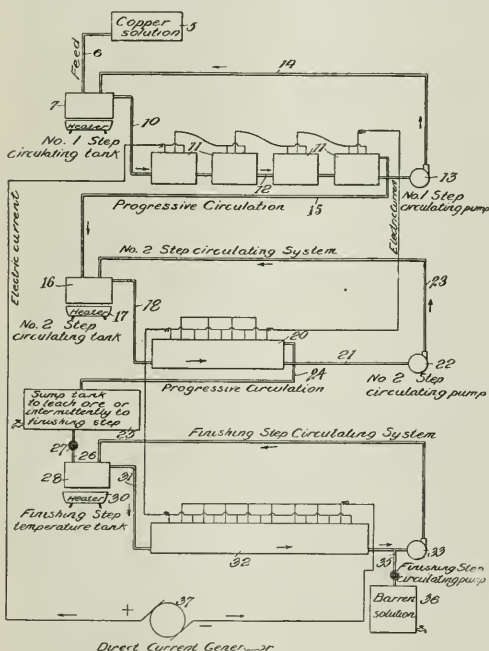


FIG. 5—DIAGRAM OF COPPER REFINING PROCESS

Fig. 6. An upper electrode C_1 forms the heating element and current is conducted down through the charge to the lower electrode C_2 . The charge in the columns h_1 and h_2 is preheated by carbon monoxide from pipes p_1 and p_2 , which is burned by admitting air at s_1 and s_2 . As the charge descends the gases given off are conducted away through passages i_1 and i_2 , any zinc vapor-

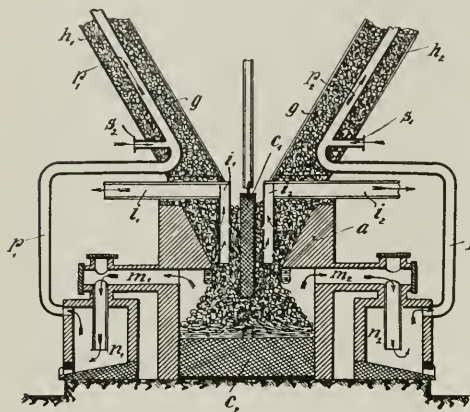


FIG. 6—ELECTRIC ZINC FURNACE

ized and tending to rise is caught by the descending charge, which acts as a sort of filter. When the charge reaches the reduction zone it is reduced and metallic vapors pass off through passages m_1 and m_2 to condensing chamber n_1 and n_2 . Any carbon monoxide going over passes through pipes p_1 and p_2 , as stated before, and is used to preheat the descending charge. (1,167,998, Jan. 11, 1916.)

Oxygen and Hydrogen

Oxygen and Hydrogen Generating System.—An electrolytic system for the generation of oxygen and hydrogen is patented by GEORGE HALTER of New York, N. Y. (assigned to Davis-Bournonville Company, New York). The system consists of an electrolytic cell with pressure regulator and purifier and automatic controlling means for maintaining the level of liquid in the cell constant. The cell consists of a rectangular iron tank divided into two compartments by an iron partition. The tank itself and the partition serve as the cathode. In each compartment is an anode in the shape of a long, rectangular, hollow basket-shaped unit, made of perforated sheet metal, electroplated as a protection against rusting. The perforations are in the form of slits, about 1 15/16 in. long by 1/16 in. wide, arranged in staggered rows. The perforations allow the inner as well as the outer surface of the anode to be used. Surrounding the anode is a diaphragm of asbestos, which fits over the anode like a sack, with extending ribs at the bottom to keep it from touching the anode. The aim is to provide large anode and cathode surface. Suitable spaces are arranged above for conducting away the oxygen and hydrogen. Upon leaving the cell the oxygen and hydrogen are conducted through separate pipes to the bottom of a pressure regulator, where the gases bubble up through water under a common head for both gases, the gases being kept separate by going through separate chambers. In passing through the pressure regulator shown in Fig. 7 the gases bubble up from inlet pipe 65, through 67 to space 69, where the pressure forces the liquid down until the gas can escape

under wall 70. In this space 69 an incandescent electric wire is placed which ignites any impurities, forcing down the piston 84, which operates to shut down the plant. The use of the common hydrostatic head for both gases in the regulator equalizes the pressure on both sides of the diaphragm in the cell. By suitable

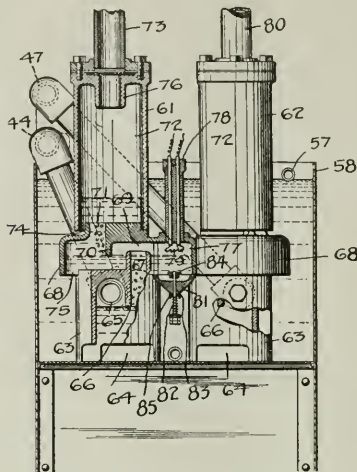


FIG. 7—PRESSURE REGULATOR

overflow arrangements in connection with the regulator a constant level of liquid is maintained in the electrolytic cell. (1,172,886-7, Feb. 22, 1916.) Another patent which was applied for before the above describes a cell much the same except that the anode is made up of wires. (1,172,855, Feb. 22, 1916.)

Nitric Acid

Fixation of Atmospheric Nitrogen.—An apparatus for producing nitric acid from air is patented by WILLIAM T. HOOFNAGLE of Glen Ridge, N. J. (assigned to Electrochemical Products Company of New York, N. Y.). In this process, the air first passes through a drier, from which it is conducted to an expansion chamber, where it is kept under reduced pressure. The expansion chamber is connected to a reaction chamber, in which the electrical discharge takes place. The object of the expansion chamber is to prevent excessive agitation of the air when it is sucked into the reaction chamber. The reaction chamber is connected to an absorber, which in turn is connected to a vacuum pump which runs continuously. In the operation of the process, which is intermittent, automatically operated valves open and allow air under reduced pressure to enter the reaction chamber from the expansion chamber. The valves then close and electricity is passed through at a high voltage and very low current by using inner electrodes of glass filled with mercury and outer electrodes of non-oxidizable metal. The reaction chamber is in the form of a cylinder with rounded bottom and having an inner core the same shape as the outer shell. The inside electrode is made up of a series of glass tubes filled with mercury placed around the outside of the inner core. The outside metal electrode is similarly placed around the inside wall of the outer shell and opposite the inside electrode. The outside electrode has a number of ribs spaced at intervals and extending horizontally toward the inner electrode. Alternating current is discharged through the space between the electrodes, the ribs forming annular discharging or con-

centrating points and partly rectifying the current. Due to the low current the heating effect is small. The necessary wattage is obtained by the high voltage. The current is applied to the air in the reaction chamber as long as the pressure continues to fall, due to the decreasing volume resulting from the combination of the oxygen and nitrogen. At the moment when the unstable oxides tend to break up into NO, causing an increase in volume and pressure, the application of the current is automatically shut off by an electrical mechanism controlled by the pressure gage. The electrically controlled valves then open, and the treated air and gases are drawn into the absorber. (1,169,824, Feb. 1, 1916.)

Oil

Electrostatic Separation of Oil and Water.—In treating oil emulsions by electricity, by passing them between high potential electrodes, short circuits may occur due to the formation of chains of globules between the electrodes. A process designed to overcome this difficulty is patented by

FRANK W. PEEK, JR., of Schenectady, N. Y. (assigned to General Electric Company). It can best be understood by reference to the illustration, Fig. 8. The oil from a receiving tank 1 passes through valve 8 into the hollow tube 9, which forms one electrode and has projections as shown. The casing 2 is made of glass, porcelain or other dielectric material, and has metal electrode 7 fastened on the outside. The electrodes are connected to a high-potential transformer furnishing a high potential and creating an electrostatic field between the electrodes. The oil passes down through hollow electrode 9 into the bottom of the container and rises up, oil being withdrawn through pipe 5. As the oil passes between the electrodes it is at first attracted to the inner electrode which has a smaller surface than the glass and consequently exists in a more intense field. The action can be clearly seen through the glass and a spark passes to each drop before it touches the electrode. When it touches it is quickly repelled to the glass where it adheres and slowly drips down, being withdrawn at 6. By passing oil containing water through this apparatus with a potential of 15,000 volts, it is claimed that the disruptive voltage was increased from 23 to 52 kilovolts using a standard gap at constant spacing for comparison. (1,170,184 Feb. 1, 1916.)

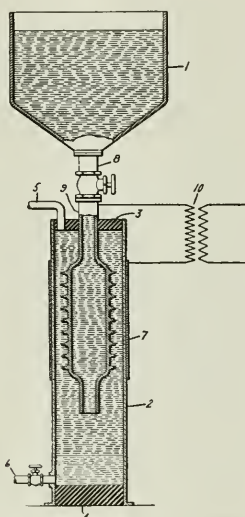


FIG. 8—ELECTROSTATIC SEPARATOR

Recovery of Metals from Waste Oils.—A patent has been issued to MATHEW E. ROTHBERG of Grafton, Pa. (assigned to Falk Co. of Pittsburgh), on a process of treatment of waste oils to recover the metals they contain either as compounds or mechanically suspended. Oils used to protect metallic coatings from oxidation, occurring as by-products, and containing some metals probably dissolved through the breaking up of the oils by heat, are first cleaned of mechanically suspended par-

ticles, then treated with a concentrated mineral acid in a suitable receptacle. The acid and oil are separated by gravity and the metals recovered from the solution. The acid used depends on the metals to be dissolved and its specific gravity must be such that an emulsion of the oil and acid is not formed. (1,170,342 Feb. 1, 1916.)

The Western Metallurgical Field

End of Brief Labor Strike at Leadville

Incipient labor troubles made their appearance on Feb. 26 at the Arkansas Valley smelter of the A. S. & R. Company, at Leadville, Col., but were ended without other effect than to reduce the scale of operations for about two weeks. Dissension apparently was spread among the workmen by a few employed on the charging floor who demanded an increase in wages of 50 cents per day, with the result that about 600 men quit work and left the plant. All who engaged in the strike were foreigners, and the majority Austrians. There was no violence and the company placed no guards on its property. Owing to the fact that Colorado is "dry" there was no drinking or carousing, and to this is attributed in large measure the lack of violent demonstrations.

The State Industrial Commission sent representatives to the district and held conferences with the strikers, explaining that under the present laws of Colorado the strike was called in violation of the provision of prior notice, and that no efforts at adjustment could be made until the men had returned to work. Interest among the strikers gradually subsided and the men began to return to work. At one time all smelting operations were practically suspended; later two furnaces were put in blast and at the present time five are in use as before the strike. With the exception of a shortage of labor, due to the fact that some men left the district, conditions are again about normal. The company has made no promises regarding a change in the scale of wages, which will remain the same as established last fall when a 5 per cent increase was granted.

New Cyanide Mill for Oatman, Ariz.

The United Eastern Company, one of the largest of the new concerns to enter the new Oatman district in Arizona, has finally decided to erect a cyanide mill. Conflicting reports regarding this mill have been current for some time, but these are now settled by an official announcement. Grading is in progress for the structure which will be erected on a site immediately below the new three-compartment shaft that is being sunk. The initial capacity will be 200 tons per day, and the design will be such that additional capacity can be secured by constructing new units.

Metallurgical and Chemical Developments in Utah

The investigation of electrolytic reduction of zinc concentrates, which has been conducted by the Daly-Judge Mining Company, of Park City, Utah, has resulted in the decision to erect a plant of this type in the immediate future. The company is one of the largest in the Park City district and has been a producer of zinc concentrates which have been shipped to smelters. Power for the new plant will be obtained from the Snake Creek hydroelectric development which has been acquired by the Daly-Judge company. The proposed reduction plant will be built in units, the first of which will have a capacity of about 35 tons per day.

The Garfield Chemical & Manufacturing Company is a newly organized concern that will erect and operate a plant for the production of sulphuric acid in the vicinity of Salt Lake City, Utah. Presumably this is the

plant which the American Smelting & Refining Company is reported to have had in mind for some time past. It is reported that the first unit of 100 tons daily capacity will be in operation by Aug. 1.

The new chloridizing-roasting and leaching plant of the Tintic Milling Company, at Silver City in the Tintic district has been completed in part and is now in operation. Two of the three Holt-Dern roasters are in use, and when the third furnace of this type and the Christensen furnace also are in operation, the capacity will be about 300 tons per day. The process is the same as was used at Park City by the same interests, and which has been previously described in this journal.

Continued Expansion in the Joplin District

Operators in the Joplin district are continuing to build new concentrating plants in order to take advantage of the high prices prevailing for lead and zinc concentrates. On local authority it is estimated that about half a million dollars will be spent on new concentrating mills in the Missouri-Kansas-Oklahoma district between now and May 1. Three of the largest concentrating mills in the Joplin district are contracted for, two of which will be built at Webb City and will have a daily capacity of 500 tons each. Two 400-ton mills are to be built in the North Cartersville district, and numerous other mills of lesser capacities have been ordered.

The latter part of February witnessed the highest price ever paid in Joplin for galena concentrates, when \$89 per ton was paid for 80 per cent lead content. The previous high price was \$88.50 in 1907. Zinc concentrates continue to bring a high price, though not as high in proportion to the price for spelter as in the case of lead concentrates.

Mineral Production of Canada in 1915

From the preliminary report on the mineral production of Canada for 1915 by John McLeish, of the Department of Mines, we note that the production was the highest ever recorded, due to the demand for metals created by the war. In Table I we give the estimated quantity and value of the metallic products, and in Table II the increase or decrease in quantity and value compared with 1914.

It will be observed that there was an increased production of all metals except silver. Ontario is the

largest gold-producing province, yielding 44 per cent of the total Canadian production. The 1915 output of gold from this province showed an increase of 51 per cent over that of 1914. The Hollinger and Acme mines in the Porcupine district contributed about one-half the Ontario gold output and the Dome mine nearly one-fifth.

Company Reports

The net profit from mining and milling operations of the *Portland Gold Mining Company*, Cripple Creek district, Colorado, for the year 1915, amounted to \$783,191, of which \$388,475 came from the mills at Victor and Colorado City. The latter plant, where high-grade ore is roasted before cyaniding, was run about to capacity and made a fair profit, handling 55,339 tons of \$24 ore. The Victor low-grade mill is reported to have had its banner year for tonnage treated and profits secured, treating 213,122 tons of ore of average value of \$3,033. At the Independence mill, which was acquired from Stratton's Independence, Ltd., on July 1, flotation has been adopted for the treatment of low-grade ore. The ultimate capacity will be 1000 tons per day. About one-quarter of this capacity is now available and the remodeling of the balance of the plant is proceeding rapidly. The Victor mill also is to be changed into a flotation plant of similar capacity. In order to meet a deficiency in the workmen's compensation act, which does not provide compensation for the first three weeks of disability, the Portland company has inaugurated a compensation fund to which each employee contributes 1 per cent of his monthly wages and the company a like amount. This fund pays an indemnity of half wages for sickness or injury during the time not covered by the state act. The Portland company also organized with the *Victindicator company* the *Direct Hospital Association* which has converted the old Gold Coin Club in Victor into a modern hospital for the benefit of employees. They contribute \$1.25 per month for which they receive medical and surgical attention and hospital facilities. Other mining companies in the district own stock in the Hospital Association.

The report of the *Braden Copper Company*, under date of Dec. 1, 1915, contains an extended statement by Mr. Pope Yeatman, consulting engineer, regarding the present conditions and future prospects of the property in Chile. The developed tonnage has been increased from 10,074,616 tons of 2.85 per cent copper ore in 1911 to 113,694,880 tons of 2.84 per cent on Jan. 1, 1916. Up to Oct. 31, 1915, the ore extracted amounted to 3,204,484 dry tons, averaging 2.25 per cent copper. The capacity of the concentration plant will be increased to 4500 tons per day. The introduction of flotation raised the recovery from 65 per cent to over 77 per cent, and it is anticipated that 80 per cent recovery ultimately will be realized. A sulphuric acid plant is in operation to supply acid needed for flotation and leaching. The smelting process has given more trouble than any other part of the work on account of the difficulty of smelting the fine concentrates. This has been largely overcome by the use of nodulizing furnaces that make a suitable product for feeding the blast furnaces. The following is a summary for the year November, 1914, October, 1915:

Product	Quantity	Value
METALLIC		
Antimony, pounds.....	961,040	\$192,208
Cobalt, metallic, pounds.....	211,610	502,388
Cobalt, oxide, pounds.....	379,219	
Nickel, metallic, pounds.....	55,325	
Nickel, oxide, pounds.....	200,032	42,193
Copper, value at 17-275 cents per pound, pounds.....	102,612,486	17,726,307
Gold, ounces.....	916,076	18,740,808
Iron, pig, from Canadian ore, tons.....	158,598	
Iron ore, sold for export, tons.....	93,444	187,682
Lead, value at 5-60 cents per pound, pounds.....	45,377,065	2,541,116
Molybdenite, pounds.....	28,600	28,460
Nickel, value at 30 cents per pound, pounds.....	68,077,823	20,423,348
Silver, value at 49-684 cents per ounce, ounces.....	28,401,735	14,088,397
Zinc, ore, tons.....	15,555	636,204
Total.....		77,046,082

	Increase (+) or Decrease (-) in Quantity	Per Cent	Increase (+) or Decrease (-) in Value	Per Cent
Principal Products				
Copper, pounds.....	+26,876,526	35.49	+\$7,424,701	72.07
Gold, ounces.....	+142,898	18.48	+2,953,964	18.48
Pig iron, tons.....	+130,555	16.67	+1,583,963	15.90
Lead, pounds.....	+9,029,300	24.88	+815,548	56.19
Nickel, pounds.....	+22,559,886	49.56	+6,767,967	49.56
Silver, ounces.....	+48,086	0.17	+1,595,234	9.65
Total metallic.....			+17,659,463	29.73

Tons of dry ore milled.....	1,106,420
Average copper assay.....	2.68
Percentage saved in mill.....	74.92
Ratio of concentration.....	11.29
Percentage copper in concentrates.....	17.68
Percentage saved in smelter.....	94.49
Tons of standard copper produced.....	16,366,788

The average cost per pound of standard copper for the year was 3.78 cents. The future cost is estimated at 6.5 cents, based on increasing capacity to 10,000 tons daily.

The Application of X-Rays to Metallurgy

About one year ago it had been proven that with the proper X-ray equipment and correct time of exposure, blowholes and similar defects could be disclosed in solid metal of considerable thickness (see this journal March, 1915, page 189). Since that time the special equipment required for this kind of work has been further developed, and several factors essential to systematic and successful routine work have been established: proportion of required time of exposure to thickness of metal; dimensions of smallest air inclusion which could be detected in a given thickness of metal; regulation of electric current to obtain maximum efficiency and best results. Other points which had to be considered were to find the direction from which further progress in the application of X-rays to metallurgical work could be expected, and to establish the technique of metallo-radiography.

By ardent research work carried on in this country's finest laboratories, these problems were completely solved. The method has already been successfully applied to research work in connection with important metallurgical problems, for instance that of casting copper (see this journal Oct. 15, 1915, p. 721). If copper is cast without additions, the metal is full of pores and blowholes, mechanically unfit, and of low electric conductivity. The use of boron flux has done away entirely with the difficulty of obtaining sound copper castings of high electrical conductivity. In the difficult research problems of this work, X-ray investigations were applied with much success; stereoscopic radio-photographs of copper castings were taken, so that not only the size, but also the relative depths of the pores could be studied. Without the use of X-rays it would have been necessary to machine off layer after layer of the many sample castings. Even then the experimenter would have had to build up a mental picture of the defects in his casting on the basis of what he has seen on each of the exposed layers. From the radiographs it was possible to see all these defects at once without destroying the castings.

The value of metallo-radiographic equipment for practical testing work will be recognized as soon as the metallurgists will have had occasion to get fully acquainted with the apparatus, using it first, for a while, in pure laboratory work. The metallurgists will then find out in what way the apparatus will assist them in the solution of their manifold individual problems. The method of metallo-radiography will be of special value in examining tools, autoclaves, boilers, high-pressure



FIG. 1—SECTION OF RADIO-PHOTOGRAPH OF STEEL CASTING SHOWING FLAW IN CASTING. THE CIRCLE SHOWS WHERE A PIECE WAS LATER PUNCHED FROM THE CASTING

cylinders, valves, saws, machine shafts, roller bearings, gear wheels, axles, cylinders and pistons of internal combustion engines, gun barrels, armor plate, submarine and aeroplane construction parts, etc.

Research work of the most interesting kind has been carried on and is being carried on at present by means of this equipment in the diffraction of X-rays. The atoms in a crystal are arranged in a definite systematic formation and their inter-atomic distances are of the same general order of magnitude as the wave lengths of X-rays. Professor Laue of Munich regarded a crystal as a ready-made natural diffraction grating for use with X-rays, but his method is not well adapted to measuring the wave length of X-rays nor to a study of crystal structures. Prof. W. L. Bragg conceived the idea of using a crystal as a reflection grating, and his excellent method possesses the advantage that the results are easily interpreted. Using X-rays and by examining the various orders of spectra from the various crystal planes, Professor Bragg has been able to assign a definite arrangement to the atoms of a crystal. As a result of the wonderful work in X-ray spectra, the Mendeleeff table of elements is to be largely replaced by the Rutherford system of atomic numbers which is based on the fact that, if the elements are arranged in the order of their atomic weights, the "atomic numbers" are proportional to the reciprocal of the square roots of the wave lengths of the characteristic X-rays. The crystallographer is now able to measure the distances



FIG. 2—PHOTOGRAPH OF EDGE OF PIECE PUNCHED FROM THE CASTING. BLOWHOLE PREVIOUSLY REVEALED IN THE RADIO-PHOTOGRAPH

between the molecules in crystals and is able to assign a definite structure to them. The chemist now knows that, at least as far as crystals are concerned, there are no such things as molecules in the sense in which the word is ordinarily used in chemistry. The whole crystal is a big complex molecule, and the chemical formula only shows the relative amounts of each element present.

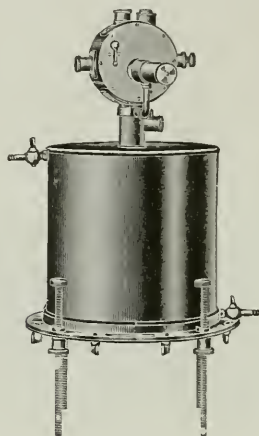
It is reasonable to assume that in metals the crystal, not the molecule, is, next to the atom, the unit to be considered. It has been found that it is possible to use the characteristic X-rays as a means of identifying the various elements, so that in the measurement of the wave length of the characteristic X-rays from a substance we have an accurate method of analysis.

The points mentioned above show the big field opened for the use of X-ray equipment in metallurgical laboratories. For both practical work and research an enormous field of study is opened to the American metallurgists. Both the equipment and full details regarding correct technique, can be furnished by Mr. Herman A. Holz, 50 Church Street, New York.

Extension of Time for Alcohol Awards.—The Russian Government has extended the time of the awarding of prizes for new methods of applying alcohol to March 1, 1917, and extended the time for receiving suggestions to September, 1916.

Radioscope for Estimation of Radio-Active Bodies

In the exact estimation of radio-active bodies the need was felt for an apparatus which combined the principles of the fontactoscope and electroscope and an apparatus has been designed embodying these principles which can be used for all known methods. The apparatus which is shown in the accompanying illustration is known as the Schocky-Willis radioscope and is constructed of heavy material and may be used with equal convenience in the field as in the laboratory for estimation of ores or fluids. The adjustable legs make it possible to place this apparatus at any desired angle. The vacuum method is used in the apparatus, the discharging chamber being constructed to withstand a high vacuum, thus making it possible to extract all the emanation from the fluid under estimation and making it possible to estimate as small an amount of fluid as 1



RADIOSCOPE

cc. The vacuum method may be combined with the boiling method.

The instrument is composed of two detachable parts, the electroscope and the discharging chamber. Amber insulation is used and instead of aluminum leaf a single conductor quartz thread is used which gives a sharply defined vision in the observation field of the microscope. The top has a capped opening with connection to the quartz thread carrier, where a condenser or voltmeter may be applied for charging. It is claimed that by proper adjustment the radioscope will accurately estimate 1/10,000 part of a microgram of radium element.

The discharge chamber is made of heavy brass and will hold a vacuum of 20 in. It has a removable bottom and screw cap for adjustment of the different electrodes which are of the round plate type. They rest on a scaled carrier pivot, which adjusts the distance between the upper and lower electrodes when the alpha ray method is used. The plate electrodes are also used when testing ores and other radio-active substances. The apparatus is supplied by the Palo Company, 80 William St., New York City.

Personal

Mr. C. G. Atwater spoke on "The By-Products from Coal Distillation" at a meeting of the Chicago section of the American Institute of Mining Engineers, held on March 9 at the Chicago Engineers' Club.

Dr. Henry K. Benson, professor of industrial chemistry at the University of Washington, Seattle, has been appointed director of the new Bureau of Industrial Research, the first on the Pacific Coast.

Mr. P. P. Bourne, formerly chief engineer of Blake & Knowles Steam Pump Works, East Cambridge, Mass., is again associated with the International Steam Pump Company in connection with special engineering work located at the main office, 115 Broadway, New York.

Mr. Frederick G. Clapp is in charge of the recently opened New York office of the Associated Geological Engineers, at 120 Broadway. Mr. Clapp is managing geologist of the petroleum division of the company, which now has offices in New York, Boston, Washington and Pittsburgh. The practice of geological engineering will be continued with especial reference to examinations and reports on oil and gas properties.

Dr. F. W. Cunningham, of Orange, N. J., has resigned his connection with the research and development work of the Newark plant of the General Electric Company to join the engineering research staff of the Powdered Coal Engineering & Equipment Company of Chicago, at which point he will be located after March 1. In his new connection Dr. Cunningham will considerably broaden the field of his activities.

Mr. A. W. Dodd has been appointed New York representative of the Granby Mining & Smelting Company, succeeding the late R. W. Conklin.

Mr. Benjamin M. Ferguson, chemical engineer, has taken charge of the Chicago office of the Permutit Company of New York City, specialists in water rectification problems.

Mr. C. J. Gadd, chief engineer of the American Iron and Steel Company, Lebanon, Pa., will deliver an illustrated lecture on the "Use of Powdered Coal in Metallurgical Processes" before the Franklin Institute on April 6, 1916.

Mr. H. E. Howe has become associated with Arthur D. Little, Inc., of Boston, as a field engineer. For the last eleven years he was associated with the Bausch & Lomb Optical Company. He is a chemical engineer and chairman of the Division of Industrial Chemists and Chemical Engineers of the American Chemical Society. Previous to his connection with Bausch & Lomb he was associated with the beet sugar industry in Michigan.

Mr. R. M. Raymond, managing director of the El Oro Mining Company, has been appointed professor of mining at Columbia University, succeeding Prof. Henry S. Munroe, who retired last June.

Mr. W. F. Roberts has been elected vice-president of the Bethlehem Steel Corporation. He has been general superintendent for several years.

Messrs. Samuel P. Sadtler & Son, Philadelphia, Pa., announce the removal of their office and laboratory from its former location on South Tenth Street to 210 South Thirteenth Street (New Davison Building), where they have taken the fifth floor and fitted it especially for their experimental and analytical chemical work.

Mr. Thomas M. Skinner, Jr., has taken the superintendency of the Mid-Continent Chemical Co., Sand Springs, Okla., and is engaged in the erection of a new chemical plant for caustic soda, sulphuric acid and silicate of soda. Mr. Skinner was formerly connected with the Western Alkali Mfg. Co. of Green River, Wyo., and the Inyo Development Co., of Keeler, Cal. His new address is Box 351, Sand Springs, Okla.

Mr. A. Van Zwaluwenburg, formerly superintendent of Nativida mill, Oaxaca, Mexico, is in New York looking up flotation.

Mr. E. P. Worden, formerly of Fred M. Prescott Steam Pump Works, Milwaukee, has been appointed chief engineer of Henry R. Worthington, Harrison, N. J.

Industrial Notes

New Benzol Plant.—The Brier Hill Steel Co., Youngstown, Ohio, will erect a benzol plant in connection with the battery of by-product coke ovens authorized some time ago.

Manganese Ore in Colon.—An American syndicate has recently opened a manganese mine at Maderiga, on the Gulf of San Blas, in the Province of Colon, about 70 miles east of Colon, according to Commerce Reports. A trial shipment of 900 tons has been made to New York.

Potash.—The National Kelp Potash Company, Long Beach, Cal., will erect a plant to be in operation early in March.

Potash.—The Chemical Refinery, Ltd., will erect a plant at St. Catharines, Ontario, Canada, for the manufacture of potash and other chemicals. The company is controlled by capital from Wheeling, W. Va.

By-Product Coke Ovens and Benzol.—The H. Koppers Co. has taken contracts to erect forty-five ovens for the Camden Coke Co., Camden, N. J., and 110 ovens for the Seaboard By-Product Co., Jersey City, N. J. The ovens are to be erected with benzol recovery plants.

New Muriatic Acid Plant.—The U. S. Steel Corporation will extend its new Donora zinc smelter, the new department being for the manufacture of muriatic acid. The plant was originally constructed for spelter and sulphuric acid manufacture.

Swedish Embargo on Chemical Wood Pulp.—A recent cablegram received from the American minister at Stockholm, according to Commerce Reports, states that the Swedish Government is disposed to grant special permission for the exportation of chemical wood pulp, if it is to be used exclusively in the United States. The minister at Christiania reports that the Norwegian Government will allow unlimited exportation of the pulp to the United States.

The Quigley Furnace and Foundry Company, Springfield, Mass., has changed its name to the Metals Production Equipment Company. A brass rolling mill department for the production of flat brass has been added, which necessitated a more comprehensive name. The company maintains a New York office at 105 West Fortieth Street.

Corkboard Insulation.—The Armstrong Cork & Insulation Company, Pittsburgh, Pa., has issued a beautifully illustrated book describing the manufacture and uses of corkboard insulation. The gathering of the raw cork, the testing and manufacture are fully described.

Water Wheel Generators.—The Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., has issued a special booklet describing alternating current water wheel generators. The booklet contains many interesting photographs.

Filter Press.—The Sweetland Filter Press Co., Inc., has just issued a new catalog, No. 12, describing the Sweetland self-dumping filter and metallic filter cloth.

The Grasselli Chemical Co. has placed contracts for plant extensions at its works in Ohio, Indiana and West Virginia for ore docks, and buildings at the New Jersey plant.

Research Bureau for Pacific Coast.—A Bureau of Industrial Research has been established at the University of Washington, Seattle. One fellowship of \$2,000, dealing with the iron and steel industry, has been established and others are under consideration. Prof. H. K. Benson, who is director of the new laboratory, delivered an address on "The Industrial Resources and Opportunities of the Northwest" at the Seattle meeting of the American Chemical Society last September (published in our issue of Sept. 15, 1915).

New Analytical Laboratory in the South.—A laboratory has recently been opened at Columbia, S. C., in the Bank of Columbia Building, by Charles W. Rice, formerly of the F. S. Royster Guano Company, Norfolk, Va. The location at Columbia is convenient for the many industrial plants in South Carolina and vicinity. The laboratory will be a general analytical one with special attention to fertilizers, cottonseed products, foodstuffs, coal and waters. It is well equipped with modern apparatus.

Drainage Conference.—A conference was held on March 8-10 at the University of Illinois for the purpose of stimulating general and technical interest in drainage, flood protection and the reclamation of swamp and overflowed lands in Illinois. The speakers included prominent engineers and professors, and many important subjects were discussed bearing on the problem of lowlands reclamation and soil conservation.

College of City of New York Lectures.—The lecture which was to be delivered on May 5, 1916, by Dr. Thomas H. Norton, as announced in our March 1 issue, has been cancelled by orders received from the United States Department of Commerce.

The Hardinge Conical Mill Co. has moved its New York office from 50 Church Street, and is now at 120 Broadway.

Northwest Mining Convention.—A mining convention will be held in Spokane, Wash., from March 20 to 25, to be participated in by the Columbia Section, American Institute of Mining Engineers; Spokane Section, American Society of Civil Engineers; Spokane Section, American Institute of Electrical Engineers, and of the Spokane Engineering and Technical Association. Arrangements have been made for the display of ores, maps, mine models, literature and photographs.

The American Society for Testing Materials will hold its nineteenth annual meeting at Atlantic City, N. J., June 27 to July 1 inclusive, with headquarters at the Hotel Traymore.

Tungsten.—A booklet has been issued by the Mojave Tungsten Co., entitled "Tungsten." The little booklet gives some of the uses and properties of tungsten and other information as to mining conditions and output in this country. In view of the scarcity of tungsten and its increasing uses it should prove interesting. Copies may be obtained from Carlisle and Company, 74 Broadway, New York.

Quicksilver in California in 1915.—Preliminary returns to the State Mining Bureau indicate a production of 12,450 flasks of 75 lb. each. Production was but very little more than in 1914, even in face of the enormous prices prevailing, although considerable work is being pushed at present. An investigation is now under way by the State Mining Bureau on concentration and the use of oil flotation of cinnabar.

Clay Products, Cement and Lime in Canada.—The production of cement, lime, clay products, stone and other structural materials in 1914 is described in

Bulletin 383 of the Department of Mines, Mines Branch, recently issued. The report shows a great falling off in building activities of all kinds due to the war. Imports and export figures are also given which should prove interesting, especially the figures on lime and clay products, including fireclay, brick, etc.

Canadian Department of Mines in 1914.—The summary report of the Mines Branch of the Department of Mines, Canada, has been issued as Bulletin No. 346. This report contains a concise summary of the work done by the different divisions during the year. The investigations carried on are usually published as separate reports. The trip taken by Dr. A. Stansfield to Sweden to study the electric smelting of iron ores is described in bulletin 344 (reviewed in this journal Jan. 1, 1916), and the extensive work done by Dr. Herbert T. Kalmus and his assistants on electroplating with cobalt is described in bulletin 334. (Full account given in this journal, May, 1915.) During the year a ceramic laboratory was established and a great many other outside and inside investigations carried out.

Metal Production in 1914 in United States.—The production of cobalt, molybdenum, nickel, tin, titanium, tungstenradium, uranium and vanadium in 1914 is described by Frank L. Hess in separate bulletin of the Mineral Resources of the United States, Part 1, No. 25. No cobalt is known to have been produced in the United States in 1914. The production of molybdenum was comparatively small, but the interest in its mining was much greater. About 400 tons of nickel was saved as a by-product in electrolytic copper refining, but the bulk of the nickel was produced electrolytically at Bayonne, N. J., as usual, from matte from Copper Cliff, Ontario. No tin was produced except a small amount from Alaska. Titanium, as usual, was produced only by the American Rutile Co., at Roseland, Va. Tungsten ore of 60 per cent WO₃ was produced to the extent of 435,000 tons. Radium, uranium, and vanadium ores were produced to the extent of 4294 short tons, carrying 87.2 tons of uranium oxide and 22.3 grams of metallic radium. This is the largest production of these ores to date. The total quantity of vanadium in the carnotite and other ores mined was apparently about 433 tons.

Another bulletin of the Mineral Resources, Part 1, No. 26, gives the production of antimony, arsenic, bismuth, selenium, and tellurium in 1914. Practically no antimony ore is known to have been smelted here in 1914, although a small amount was isolated electrolytically from the anode mud left in electrolytic lead refining. The output of white arsenic (arsenious oxide) was 4670 short tons. Bismuth was produced in small amounts, from one mine as a by-product of the smelters. Selenium was produced to the extent of 22,867 lbs., but very little tellurium is known to have been saved.

New Construction for United States Steel Corporation.—Improvements at the Gary, Ind., plant of the United States Steel Corporation to cost \$25,000,000 were announced a short time ago by Chairman E. H. Gary. A first-class tube plant will be built, including ore docks, yards, blast furnaces, and all the other necessary shops, mills and auxiliary departments. This brings the total expenditures announced since the beginning of the year up to \$65,000,000. The former expenditures announced included the erection of batteries of by-product coke ovens at the Youngstown plant of the Carnegie Steel Company and a bar mill plant. Work will be started this spring on the extensive by-product coke ovens at Youngstown.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Aqueous Bath Apparatus

(Concluded)

679,050, July 23, 1901, Raoul Girouard, of Westbrook, Me., assignor to S. D. Warren & Company, of Boston, Mass.

Relates to a liquid-feed device for electrolytic cells and similar apparatus, and consists of a supply vessel which is kept filled by a ball valve, or the like, and which is provided with a restricted outlet, such as a small bore tube, feeding into a delivery device consisting of a container having an outlet in its vertical wall of greater capacity than the small bore tube. During operation, the liquid enters the container slowly and passes through the outlet in drops, separated by bubbles of air, the size of the drops and of the air-bubbles being determined by the size of the outlet tube. The drops of liquid from the outlet tube fall into the supply funnel of the electrolytic cell at a continuous rate, and provide a substantially uniform supply of liquid.

697,788, April 15, 1902, David Wesley Blair, of Perth Amboy, N. J., assignor of one-half to James C. McCoy, of Perth Amboy, N. J.

Relates to a crane for lifting anodes and cathodes out of electrolytic tanks. The crane is provided with long parallel horizontal supporting arms capable of a small longitudinal movement, and from which depend hooks capable of being turned to approach each other, or to be separated further apart. Anodes are generally supported from the sides of the tank by lugs, and when it is desired to remove a set of anodes, the hooks are separated and lowered to engage the lugs; when it is desired to remove a set of cathodes the hooks are turned toward each other, and lowered, the cathodes generally being suspended from rods which may be engaged near the center. One set of hooks on the crane thereby provides for raising both anodes and cathodes.

This concludes the patents in the class of Aqueous Bath, Apparatus, prior to 1903.

Aqueous Bath, Cathodes

61,074, Jan. 8, 1867, John L. Kendall of New York, N. Y., assignor to himself and R. H. Trested, of same place.

Relates to making dies for making imitations of straw hats from a suitable prepared fabric. The die consists of two parts, the outer of which is made by electroplating copper upon the graphited surface of the outside of a model straw hat, removing the straw, and reinforcing the copper deposit by a suitable fusible alloy. The inner, or counter-die is made by coating the copper deposit with a thin uniform layer of clay or the like, filling the clay lining with fusible metal, and after cooling, separating and cleaning. The fabric imitation is pressed between the inner and outer dies.

171,464, Dec. 21, 1875, William E. Worthen and Richard S. Gillespie of New York, N. Y.

Relates to making statuettes, etc., by first forming a core of plastic conducting material, made of powdered coke, charcoal, or plumbago, united by a waterproof binder such as asphalt. The core is then coated with plumbago as usual. The shaped and coated core is a conducting mass, and will serve as a cathode for deposition. The conductivity of the core is increased by increasing percentage of coke dust, the particles of which

have many sharp points making better contact with each other. The coated core is electroplated with copper or other metal, and is suitable for architectural or other purposes.

193,922, Aug. 7, 1877, Henry R. Cassel of New York, N. Y.

Relates to making rolls or cylinders having figured surfaces for producing imitation morocco leather, etc. A split cylindrical mold is lined with leather, etc., with its figured surface exposed. The figured surface is covered with graphite, the split molds are united and enclose a concentrically supported anode of copper. The mold and anode are suspended in a copper sulfate solution, and the surface of the leather electroplated to a suitable thickness. When completed, the mold and anode are removed, the deposited copper cylinder separated from the leather, and mounted upon a suitable mandrel for use as a roll for embossing leather, etc.

198,209, Dec. 18, 1877, Alexander E. Outerbridge, Jr., of Philadelphia, Pa.

Relates to making metallic leaf, such as gold-leaf, by electrodeposition. The deposit is effected upon an extended smooth surface of metal, or non-metal, which is provided with a conducting coating such as bronze powder. When the deposit is completed, the metal or non-metal support is removed by a suitable solvent, such as dilute nitric acid, dilute perchlorid of iron, alcohol, etc., and the gold leaf collected upon a glass sheet. It is then floated on water for washing, and again collected. It is then packed in the usual "books." The patent states that gold foil thinner than that made mechanically may be obtained in this manner.

202,969, April 30, 1878, James W. Tufts of Medford, Mass.

Relates to the making of articles by electrodeposition, and consists in forming a mold of the shape desired, by recessing a surface, electrodepositing upon the surface and recess, and after completion cutting away the metal deposited upon the surfaces which served as a support for the irregular extensions of the formed article.

276,777, May 1, 1883, Noah L. Cochen of Brooklyn, N. Y., assignor to himself, Timothy Youle Brown of New York, and George Brown Walton of Brooklyn, N. Y., trustees.

Relates to the manufacture of rolls by electrodeposition, the rolls to be used for making imitation morocco leather, etc. The leather is cut into strips of suitable width, made acid-proof by suitable oils or varnish, wound as a helix upon a true cylinder with the irregular surface in contact with the cylinder. The leather is retained in its position by a suitable paste or cement, and is backed by a supporting cement. The cylinder is then withdrawn, the surface of the leather metallized, and placed as cathode in an electrolytic bath. The anode consists of a helix of copper having about the same surface as the cathode. After deposition, the leather is removed from the copper deposit, and the latter turned true inside and mounted upon a mandrel.

282,879, Aug. 7, 1883, Davis Garrett of Pittsburgh, Pa., assignor of one-half to Alexander Gordon of same place.

Relates to the manufacture of parabolic reflectors for use as headlights, etc. A negative is made of easily fusible metal, which is ground and polished, and upon this an electrodeposit is made without the use of graphite or other conductive coating. After a sufficient coating has been deposited the fusible metal negative is melted out and the surface of the deposited metal polished and silver-plated if desired.

290,949, Dec. 25, 1883, William Wallace of Ansonia, Conn.

Relates to the manufacture of hollow articles by elec-

trodeposition and to the method of separating the deposit from the mold. In the making of a headlight reflector, a hole, which is temporarily closed, is made through the solid core upon which the deposit is made, and after the deposition, water under high pressure is forced through the hole and between the deposit and the surface of the solid core, thereby separating the deposit from the core.

313,805, March 10, 1885, John J. Callow of Cleveland, Ohio.

Relates to the manufacture of perforated or recessed metal goods, suitable for stencils, printing, etc. A glass plate is etched at predetermined places, to a suitable depth, the etched portions then roughened with a sand blast, the rough surfaces are then coated with graphite and electrodeposited upon, the deposition being continued until a sufficient thickness is obtained. It is then removed and smoothed, trimmed and finished.

340,460, April 20, 1886, Lewis H. Rogers of Kansas City, Mo.

Relates to the manufacture of wax forms for the production of hollow articles such as parabolic mirrors. Suitable male and female metallic molds are made, and secured to waterjackets. Wax is supplied to the space between the molds, the latter are pressed together, and steam admitted to the waterjackets to melt the wax. Pressure is then applied to compress the wax and to destroy any air bubbles that may be on the surface of the molds. Cold water is then supplied to the waterjackets to chill the wax form, after which it is removed and coated with graphite and electroplated.

396,911, Jan. 29, 1889, Henry F. Belcher of Irvington, N. J.

Relates to the manufacture of mosaics of glass, and refers to his prior patents for such articles. The pieces of glass are suitably secured in the openings of a metallic frame having the desired design, and a deposit of copper produced upon the frame so as to overlap the edges of the glass pieces on both sides, thereby securing them permanently in place. Different metals may be deposited at desired places, thereby producing more ornamental results.

454,381, June 16, 1891, Alexander Carl Reinfeld of Vienna, Austria-Hungary.

Relates to preparing cathode surfaces for the easy removal of a deposit. A cathode having a nickel surface, which may be solid nickel, nickel alloy, or nickel plate, is cleaned and then treated with a weak oxidizing solution, such as potassium chromate, etc., which produces a very slight film of oxide. The oxide surface may then be rubbed with a soap-like mixture to further polish it. It is then connected as cathode and immersed in the electrolyte. Deposits formed on this surface are said to be readily removed. After each deposition, the nickel surface requires reoxidation. The process may be used for the production of very thin gold-leaf, and for other uses.

480,186, Aug. 2, 1892, Francis Edward Elmore and Alexander Stanley Elmore of Leeds, assignors to Elmore's American and Canadian Patent Copper Depositing Company, Limited, of London, England.

Relates to the manufacture of tubes by electrodeposition of metal upon a mandrel, the deposit being burinised as it is formed. The deposit adheres to the mandrel and requires mechanical treatment to loosen it. This is effected by pressing a roller against a thin deposit upon the rotating mandrel, and advancing the roller along the length of the mandrel, thereby loosening the entire deposit except at a narrow band at one end. The deposit is then continued to the desired thickness, when the narrow adhering band is cut off, and the tube removed.

485,919, Nov. 8, 1892, Francis Edward Elmore of Leeds, assignor to Elmore's American and Canadian Patent Copper Depositing Company, Ltd., of London, England.

Relates to the manufacture of tubes by electrodeposition of metal upon a mandrel. The mandrel consists of a perfectly smooth tube which may have been made by electrodeposition; the surface of the mandrel is covered with a fusible material such as paraffin, or fusible metal, which is carefully smoothed. The paraffin is coated with graphite, and electric contact made with the mandrel by removing portions of the paraffin, the graphite filling the openings. Or the paraffin may be mixed with salt and after it is applied, the salt dissolved out, leaving pores which are to be filled with graphite. The coated tube is then electroplated to the desired thickness, the fusible material thereafter melted, permitting the removal of the tube.

510,013, Dec. 5, 1893, Carl Endruweit of Berlin, Germany.

Relates to the manufacture of so-called metal paper, such as nicked or bronzed paper. The deposit of metal for the paper is deposited upon a highly polished brass or nickel surface which has been treated with a 5 per cent solution of potassium trisulfid (K_2S_3) or the like, the solution containing a little alcohol to remove grease, etc. The cathode so treated has an effective coating permitting the easy removal of deposits. The cathode then receives a thin deposit of copper or nickel or other metal, in a neutral electrolyte, and then a deposit of the metal in an acid electrolyte to the desired thickness; it then receives a thin deposit of zinc from a zinc electrolyte. The zinc deposit is treated with a solution of ammonium hydrosulfate, mercaptan, sulfid of allyl. The sheet of paper, coated with starch paste containing one fourth of animal glue, is then pasted on the metal deposit. The foil is removed from the cathode. Coppered paper may be rubbed with a mixture of gold or silver cyanate with carbonate of potash which produces a gold or silver paper.

554,243, Feb. 11, 1896, Samuel Crump of Spokane, Wash.

Relates to a method of producing molds for paper-making machines, either of the cylinder, Fourdrinier or hand type, and consists in electrodepositing copper upon the wire screen in pre-arranged patterns, thereby closing the meshes of the wire screen, and forming open patterns in the wire mesh for the reception of the paper pulp. The open pattern is produced by covering the wire screen with wax or other resist, and electroplating upon the uncovered portions to the desired thickness. The wax resist is then removed and the screen is ready for use.

574,843, Jan. 5, 1897, William H. Winslow of Chicago, Ill.

Relates to the forming of tile-sections into a body, the tiles may consist of opaque pieces, or of glass, particularly for securing heavy vault-light prismatic tiles into a frame, by electrodeposition of metal in the spaces between the tiles and the frame. The frame is suitably supported and the prisms properly placed in the openings. Metallic strips are placed between the prisms, leaving spaces for electrodeposited metal, to serve as cathodes. If desired, the spaces between the prisms and metallic strips may be filled with metal filings to save some electrodeposited metal. The frame with the prisms, etc., is now immersed in the electrolyte, and deposition effected, the metal filling the spaces and firmly securing the prisms. The deposited metal may extend beyond the surfaces and overlap the edges of the prisms if desired.

577,070, Feb. 16, 1897, Harry Sandham of Spokane,

Wash., assignor to Samuel Crump of same place.

Relates to the production of molds for paper-making machines, and consists in coating the obverse side of the screen with a suitable resist to produce a design thereon, then to the reverse side securing a piece of waxed paper which has had its wax surface metallized or made conducting by graphite. The screen and waxed paper are now immersed in the electrolyte and the meshes in the screen not closed by the resist are closed by the electrodeposit which forms a solid sheet of metal with the wire cloth. The screen is then removed, the resist washed off with a suitable solvent, and the screen with the design upon it is ready for use.

Book Reviews

The Mining Manual and Mining Year Book for 1916.

By Walter R. Skinner. 957 + lxxi pages. Price 15s. net. (Post free in U. S. 17s.) London: Walter R. Skinner.

This is the thirtieth consecutive yearly issue of this work. It covers every section of the London mining market and many mines whose shares are not dealt in at present on the London Stock Exchange, including the most important companies in North and South America. The alphabetical arrangement adopted last year has been continued and should prove the handiest form for quick reference. The supplementary index which contains the names of companies which have been considered to be of not so much interest, has been separated this year from the index proper and placed at the end of the book to avoid confusion. In the dictionary of mining terms those used in Russian reports should prove helpful. The preface contains a review of mining conditions in 1915 and an appendix of several pages is added containing the latest registrations, which completes the information up to within a short time of publication (February, 1916). The high standard of the work has been maintained as heretofore.

The Journal of the Institute of Metals, Vol. XIV, edited

by G. Shaw Scott. 289 pages, 15 illustrations. Price, 21s. net. Westminster, S. W. The Institute of Metals.

This is the second volume of 1915 and contains the proceedings of the May lecture meeting and the seventh annual autumn meeting. The papers and discussions are very interesting and deal with a variety of subjects. A lengthy paper on "Specifications for Alloys for High Speed Superheated Steam Turbine Blading," by W. B. Parker, is followed by quite an extended discussion. There is a paper on "The Constitution of Brasses Containing Small Percentages of Tin," by O. F. Hudson and R. M. Jones, which should prove of interest to brass founders. On the same subject there are two papers by D. Meneghim; one on "Structural Changes in Industrial Brasses" and one on the "Hardness of Copper-Zinc Alloys." There is a paper on a "Thermostat for Moderate and High Temperatures," by J. L. Houghton and D. Hanson; a paper on "Crystal Twinning by Direct Mechanical Strain," by C. A. Edwards; a paper on "The Physical Properties of Metals as Functions of Each Other," by A. H. Stuart; a paper on the "Copper-rich Kalchoids," by S. L. Hoyt and P. H. M. P. Brinton; a paper on the "Micro-chemistry of Corrosion in Gun Metal," by C. H. Desch and H. Hyman; a paper on the "Widmanstätten Structure in Metals and Alloys," by N. T. Belaiew, and a note on the "Detection of Internal Blow-Holes in Metal Castings by X-Ray," by C. H. Tonamy. The May Lecture of Sir J. J. Thomson, which completes this work is a valuable contribution on "The Conduction of Electricity Through Metals."

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The Flotation Process and Our Universities

The flotation process is sweeping the metallurgical world with an elemental dynamic power. Two things will be needed to make its victory complete:—a speedy termination of the litigation on the fundamental patents and the evolution of a universal flotation theory which transfers the flotation process from empiricism into applied science. How long the patent litigation will last no one knows; it seems utterly beyond control. But the evolution of a flotation theory is not, although it is true that so far practice has out-distanced theory by many a mile.

There is a wonderful field for research opened here for our universities. An immense amount of work has already been carried out at some of them. Prof. W. A. Whitaker at the University of Kansas is doing excellent work; so does Dorsey A. Lyon with his associates of the Bureau of Mines in co-operation with the University of Utah, and he deserves highest credit for his efforts to organize the work of the many different investigators in this field into something like a harmonious unit. There are many others equally active. But the main work remains to be done.

One thing is certain. If a universal flotation theory is to be developed, it must be built up from fundamental facts, gradually, step by step, in some such way as sketched in the intensely interesting remarks of Mr. G. D. Van Arsdale in the flotation discussion at Ottawa last month (see page 325 of our last issue). No purely chemical theory will do nor a physical theory nor an electrical. The elemental force of the flotation process sweeps away the man-made distinctions between different sciences. What is required is a combination of the viewpoints of chemist, physicist, electrician and metallurgist. Indeed, here is a wonderful field for our universities.

Industrial Canada and Niagara Falls

Our esteemed contemporary, *Industrial Canada*, in its March issue prints under the heading, "The Power Famine at Niagara Falls," the three interesting papers by Messrs. Hooker, Landis and Tone (see pages 240, 260 and 261 of our issue of March 1), and introduces them by the following highly suggestive editorial remarks (the italics are ours):

"What is Canada's interest in a further development of electrical energy at Niagara Falls?

"Necessity for bringing about a condition of economic and industrial independence is driving the United States toward the point where further development of Niagara power is becoming absolutely imperative. At two meetings last month of sections of the American Electrochemical Society, one held at Niagara Falls, and the other at New York, addresses were delivered which showed conclusively that from the United States standpoint at any rate, there would have to be considerably more power development at

Niagara Falls, if the work of providing the requisite domestic supply of basic chemical products was to be extended further. As one speaker put it, in any program of industrial preparedness and self-containedness, chemical preparedness and chemical self-containedness play a big part, and its crux is more Niagara power.

"After grasping the import of two or three addresses delivered at these meetings, Canadian manufacturers may well ask what interest the Dominion should take in a question which certainly has an international as well as a national aspect. *If the United States has reached its limit of production under existing conditions, is there not an opening here for an immediate development by Canada of certain electrochemical industries which will provide a part at least of the chemical products now in strong international demand?*"

In the few comments which we will make, we have to perform a duty, both pleasant and unpleasant, in recalling nothing but plain incontestable facts. It is our pleasant duty to pay a compliment to the intelligent way in which Canada has handled its industrial electrochemical problems in the past. This has been characterized by far-sightedness and directness and by a hearty co-operation between government and industry. How the Canadian government has understood its opportunity and responsibility in this matter, has been finely shown by the extended activity over many years of its Department of Mines under Dr. Eugene Haanel, whose work in furthering electric furnace development has become classic. As a British contemporary once put it with perfect truth, this work "stands a monument of legitimate government activity, directed with intelligence and achieving its goal."

It is our unpleasant duty—but a plain duty nevertheless—to recall how industrial electrochemical developments on the Canadian side of Niagara have been helped nicely along by what Canadians may call "good luck"—that is, the power famine on the United States side, increasing steadily in seriousness from year to year. The calcium cyanamid industry was thus expatriated from the United States; what this means to the United States from the viewpoint of national preparedness was fully discussed in our issue of March 1. The Norton Company was forced to go to Canada for the erection of its silicon carbide plant. And there are others. What may be expected to follow might be prophesied with gruesome logical consequence from the present conditions on the United States side of Niagara if not radically changed in short order. We will not prophesy. We will simply state the facts.

The American electrochemical industries at Niagara are of such unique conception and execution, and of such overwhelmingly broad importance for the whole life of this nation, that when the really big achievements of American scientific and industrial genius are mentioned, the Niagara electrochemical industries should be mentioned among the first. They are an achievement the United States has a real right to be proud of. And the fact is that these industries are now almost forced to go begging for the most fundamental needs of their existence—power. And the fact is that in the electrochemical plants on the United States side of Niagara from 125,000 to 150,000 hp. are now used which are being transmitted from the Canadian side of the falls, and that this importation de-

pends on permits revocable by the Canadian government.

We hear so much talk now about national preparedness and national self-containedness. If the above statement of facts will induce a little thinking about this particular phase of preparedness, we need not add a further word.

After Villa, What?

Engineers will hail with unconcealed delight the movement started by the United States which may result in making Mexico a safe place for civilized man to pursue peaceful vocations, as well as prove to both bandit and so-called patriot that our limit of endurance has long since been transgressed. Villa's boast that he would force intervention is not the first sentiment of that kind to be expressed. For several years past American engineers returning from trips into Mexico have brought word of an undercurrent of similar feeling that existed among well-to-do and influential Mexicans, who saw no light of leadership among the squabbling factions. To them the aid of the United States seemed indispensable in restoring peace to their troubled country; and if that aid was not forthcoming in a friendly way and of our own initiative, it would be forced—even by acts of violence on their part.

In the meantime our course of inaction has bred among the rank and file of Mexicans a sense of disrespect for our country and its citizens. We have been forced to abandon legitimate property and the peaceful pursuit of business. Engineers have been wantonly murdered or run out of the country; and those who left took their departure amid the threats and jeers of an irresponsible populace, taunting them with cowardice, ridiculing their government and insulting the flag that was supposed to typify the privilege and right of sanctuary. The cap sheaf of daring and boastful insolence was the invasion of our borderland and the murder of innocent citizens.

These things are past and have forced an action on our part, the final result of which no man can foresee. Our punitive expedition has a definite objective, the capture and subjection of a confessed bandit; but the consequent developments may grow beyond our control and lead to unexpected complications. Our singleness of purpose presumes the sincerity and co-operation of Carranza and the loyalty of his constituents. The quality of the latter is notoriously base, its quantity almost minus. The average untutored Mexican transfers his allegiance with great facility, espousing the cause and supporting the man of the hour. In this lies an element of danger and uncertainty to our expedition, the purpose and magnitude of which may be altered by unforeseen developments. Besides Villa there are other unscrupulous aspirants for Mexican power who might unite with him against an assumed common enemy.

Once begun, however, we hope some definite object may be achieved through our action, both for the good of Mexico and the protection of our own interests. Our long forbearance must disarm suspicion of our good

intentions. If our expressed purpose has to be changed to meet new conditions, let it be followed to a conclusion more final than was achieved at Vera Cruz, so that Mexico may be helped in her distress and made ready for the tremendous development that awaits her and in which American engineers are bound to be a potent factor. And, finally, may no tactical blunder or scandal of unpreparedness or tragedy of "embalmed beef" mar the success of our undertaking.

The Steel Corporation Report

The report of the United States Steel Corporation for the year 1915, just published, is the record of a wonderful year. Its totals, viewed in the abstract, are not remarkable. What was noteworthy in the year was the sweeping change that occurred, from operations at less than 50 per cent of capacity at the beginning of the year, to operations at capacity, in some instances at more than rated capacity, at the close of the year, and from earnings of \$1,687,150 in January to earnings of \$17,722,682 in December. The total earnings of the year, \$130,396,012, after payment of interest on subsidiary company bonds, were less than in six of the thirteen years that preceded, while the tonnage of steel products in the form in which sold, 11,762,639 tons, was less than in two preceding years.

While the 1915 earnings were exceeded in six preceding years, there were larger dividends paid in those six years, to such an extent that in only two of the six was the surplus after dividends larger, those two exceptional years being 1906 and 1907, and in both of them there were large appropriations for new construction, whereby the unappropriated surplus in 1915 was the largest for any year in the corporation's history, the amount being \$44,260,374, and it is interesting to note that the cash on hand increased by 73 per cent as much, to \$94,083,805, or \$26,930,241 more than reported at the close of any previous year.

There is every reason to believe that the cash on hand has been increasing rapidly since the close of the year. The December earnings were sufficient to meet all charges and dividends and leave almost \$10,000,000. The earnings have been increasing since December, and promise to continue increasing for some time to come. While there is much new construction in progress, a part of such expenditures is met by certain charges made against the earnings, while the strictly capital expenditures cannot be running at more than a relatively small fraction of \$10,000,000 a month. Steel prices have been rising up to date, and month by month old and low-priced orders are worked off the books, whereby monthly earnings have been increasing since December and promise to continue increasing. With a stationary market from this date, and full operations, earnings would increase for many months.

Comparing the tonnage output in 1915 with that of 1913, the last year of measurably full operations, there was a decrease of 5 per cent in the tonnage of steel products in the form in which sold. The individual items showed wide variations. There were increases of 66 per cent in billets and sheet bars, etc., and 23 per

cent in wire products, while there were decreases of 41 per cent in rails, 27 per cent in heavy structural shapes, 23 per cent in tubing and pipe, and 27 per cent in finished structural work. These great changes reflect the disturbances caused by the war. The demand for large steel rounds for shells is not reflected in the figures, for the reason that merchant bars, hoops, bands, skelp, etc., are lumped in the presentation, the total showing an increase of 5 per cent.

Considerable interest has been manifested in the effect that might be produced upon the production statistics through the manufacture in 1915 of so large a tonnage of shell steel, involving a heavy cropping from the ingot. Perhaps an influence can be traced, even though the shell steel comprised only a relatively small proportion of the total steel made. The division of the Steel Corporation's tonnage in general was not such as to suggest a larger production of scrap in finishing in 1915 than in 1913, but it is to be observed that in 1913 the proportion of steel for sale to ingot production was 74.3 per cent, and to pig iron produced 87.9 per cent, while for 1915 these proportions dropped to 71.8 per cent and 86.2 per cent respectively, while it is also to be observed that in 1913 the production of pig iron to ingots was 84.6 per cent, while in 1915 it was 83.3 per cent.

Whatever may have been the effect of the war demand in increasing the Steel Corporation's supplies of scrap in 1915, the new construction program looks to a larger employment of pig iron, duplexing being the outstanding feature. A part of the new construction program had not been the subject of public announcement prior to the issuance of the annual report. Of straight open-hearth furnaces there are only ten being built, four at the Lorain works of the National Tube Company, one at the Newburgh works, Cleveland, of the American Steel & Wire Company, and three at the Ohio works and two at the Clairton works of the Carnegie Steel Company. Two complete duplexing plants are being built, one at Gary and one at the South Chicago works, each comprising two 25-ton converters and two 100-ton tilting open-hearth furnaces. At the Donora works, in the Pittsburgh district, two 25-ton converters are being installed, to be completed June 1, to operate in conjunction with the present open-hearth plant, which comprises thirteen stationary furnaces. With the recent completion of the Duluth plant the Steel Corporation's steel ingot capacity was brought close to 20,000,000 tons, and the additions now under way will easily increase the capacity to 22,000,000 tons or more.

The by-product coking construction program is equally impressive. Retorts are being built as follows: Clairton, 200; Youngstown, 210; Central furnaces, Cleveland, 180; Lorain, 225, making a total of 815 retorts. These are in addition to 1262 retorts in the North and 280 in the South, a total of 1542 retorts, so that the number of retorts is being increased by 55 per cent. The coking capacity is being increased much less, of course, since the corporation has 22,153 beehive ovens in the North and 2974 in the South.

Readers' Views and Comments

Waterpower Development

To the Editor of *Metallurgical & Chemical Engineering*

Sir:—There are two great conservation bills before Congress, the passage of which means so much to the economic welfare of the United States that they are entitled, I believe, to your careful consideration and earnest support. These are the bills for enabling and encouraging development of the unused waterpowers in the navigable streams and in the public domain. Because of widespread misinformation and misunderstanding concerning the waterpower business, and because of misapprehension in many minds as to the kind of legislation necessary to bring about waterpower development, there is danger that these bills may be passed in such form as will defeat their main purpose, and actually discourage waterpower development instead of encouraging it.

To secure waterpower development by private enterprise, terms and conditions must be such as will attract investment. With Europe impoverished by war, development must be financed here, and waterpower securities must compete with other forms of investment. Under present laws, for several years past, waterpower development in the United States has been practically at a standstill. A few comparatively small powers have been developed in the West, in the national forests and national parks, in localities where growth of city utilities or need for irrigation, or both, have created a high-priced market, or where conditions have otherwise been exceptionally favorable. No large hydro-electric plants have been built in recent years. Recent reports of the Forest Service show that the average size of power plants built in the national forests under the present revocable permit system is less than 6,000 horsepower, and that permits have been issued for large developments aggregating more than 1,500,000 horsepower, of which none has been built or is being built. I know from personal investigation that efforts to finance these larger plants have failed, and that they cannot be built under present laws.

In ten years past only eight waterpower plants, aggregating less than 140,000 horsepower, have been built upon our navigable streams under the general dam acts of 1906 and 1910. President Wilson, Secretary Lane and committees of both Houses of Congress, after careful study, have announced their belief that new laws are necessary to stimulate waterpower development.

During the last ten years, 1,200,000 horsepower of hydro-electricity has been developed in Europe for use in atmospheric nitrogen establishments. A number of large enterprises of this nature have been planned in recent years, in the South and the West, but they cannot be financed under present laws. The stagnation in waterpower development is not only wasting unnecessarily our fuel supply, but is preventing the establishment of new industries and putting the brakes on national prosperity. One large factory, with \$2,000,000 invested in buildings and machinery especially designed for making water wheels, was shut down for ten months last year, and has exactly one small wheel at present under construction. It is estimated that more than 2,500 engineers in the United States, formerly employed in hydraulic construction, are now out of work.

We are talking of military preparedness, but are wholly dependent upon foreign supplies of saltpeter from which to make nitric acid, an essential in the man-

ufacture of explosives. Our farmers are paying tribute to the Chilean monopoly on every pound of nitrates used in agricultural fertilizers. Capital will not develop the waterpowers necessary to the establishment of electrochemical industries which would give us military, agricultural and industrial independence, because present laws do not guarantee security of investment or offer hope of reasonable return. It is believed by men who know the practical side of the subject that the Shields bill and the Ferris bill, as amended in the Senate, will offer this needed incentive to investment, and that their passage will be closely followed by extensive development.

The Shields bill received the full endorsement of Lindley M. Garrison, former Secretary of War, whose testimony on the subject before the House Committee on Interstate and Foreign Commerce should be carefully read. An editorial in the *Outlook* of Feb. 9, 1916, states clearly and forcibly the features of legislation necessary to protect public rights. All of these features are included in both the Shields bill and the Ferris bill as amended by the Senate Committee on Public Lands.

Both of these bills retain to the public all title in water rights and power sites, where these are now publicly owned, granting only permits or leases for use for fifty years, at the end of which period the Government may take over all parts of the plants dependent for their usefulness upon these leases or permits, at a fair value to be decided by mutual agreement, or by the Federal courts. No allowance is to be made for any unearned increment or value in any lands or rights granted or leased by the Government or acquired by condemnation under any powers conferred by the acts. During the leasing period, intrastate service and rates are to be subject to State regulation, and interstate service and rates by the Interstate Commerce Commission.

On the ground that use is the highest form of conservation of waterpowers, and to discourage speculation, leases and permits are to be revocable if development is not made within a reasonable time. A moderate rental for public lands used is to be paid by the power companies; also a Federal charge for the benefits derived from Government storage of water. Any attempt to make these powers a source of large Government revenues would naturally add to cost of development and to power prices, which would discourage use, since the lower cost of construction and the greatly increased efficiency of steam plants make their competition with the average waterpower very close.

There is talk of a Water Power Trust. Actually, no such thing exists. It is true that there is a limited number of waterpowers, and that it is not generally possible to have competition between one waterpower and another. Some of our biggest and best waterpowers are located in the mountains of the West, remote from cities. They can be and should be utilized for creating cheap power for irrigation, for electrification of railroad trunk lines, and for great chemical and manufacturing industries to make available the ores and minerals in these waste regions. Present laws, however, are prohibitive of development for such uses. This leaves the corporations operating public utilities in the cities as the largest users of power, and for these reasons the utility corporations naturally control a large percentage, not only of the developed waterpowers, but also of the steam power of the country.

There is nothing abnormal or alarming about this situation, excepting in the fact that so much coal and oil, and so little waterpower, is being used to generate electric current. So far as the control of waterpowers by the utility corporations is concerned, it means simply, and only, that what waterpowers are in use are being used to supply the power market where they are of the greatest value. Power can be transmitted economically for only limited distances, and if waterpowers are to be used at all, they must be used for supplying power within the zone of economical transmission. Where the use of a waterpower will reduce the cost of power and conserve the fuel supply, shall we leave it unused because the most beneficial use can be made by a corporation which, under state and municipal charters with which Congress cannot interfere, controls the distributing system supplying the natural market for power?

Distribution of power, with other public utilities, is considered by most economists to be a natural monopoly—a service that can be better and more economically rendered by monopoly than by competition. President Van Hise, of the University of Wisconsin, in his book on the subject, points out that the generation and distribution of power is a natural monopoly and should be recognized and treated as such. Experience has shown that monopoly in the power business increases diversity of use of current, resulting in increased load factor and consequent reduction of unit cost. Shall we refuse to allow the use of waterpowers to the corporations controlling natural monopolies, and attempt to force unnatural and uneconomic competition in the distribution of power? Shall we, in blind prejudice, compel these corporations, because their business is a natural monopoly, to go on burning coal and oil where they could reduce the cost of their power by using waterpower?

Suppose these power companies were all burning wood, that the government controlled the coal supply, and that to substitute coal for wood under the powerhouse boilers would cheapen cost of power. Who would be so foolish as to propose that these companies, because they held local franchises giving them control of the natural monopoly of the power business, should not be allowed to burn coal, or that the government should fix the price of coal so high that it would be cheaper for them to go on burning wood and denuding the forests? Still this is the attitude of some men who are trying to scare the country with a Water Power Trust bugaboo, and who are urging that waterpower development should be discouraged by high rentals or taxes on use of water rights and power and dam sites.

There are a few sections where utility corporations having a monopoly of present waterpower development are opposing this legislation because they do not want further development that would lead to the establishment of new industries, increase demand for power, upset the conditions they now enjoy, and possibly bring about reduction in power prices.

Utility corporations and power companies are all subject to state regulation as to their rates and service. The pending bills make companies operating under them subject to Federal regulation where the states do not exercise this power. The cheaper the cost of their power, the lower rates they will naturally be compelled to offer to consumers. Under the proposed legislation, the power companies will not have the opportunity to capitalize or exploit any unearned increment or monopoly value in what is now public property, because they will not be given any title or any rights extending beyond the leasing period, in such property. How, then, can the public be anything but benefited by permitting the power companies to develop maximum power at minimum cost?

By all means, let us have free discussion and criticism of legislation, but let the criticism be based on knowledge and understanding of the facts, and actuated by intelligent wish to make legislation beneficially constructive. Let's get away from personalities and prejudices and consider this whole subject on its merits and demerits.

HERMAN B. WALKER.

Water Power Development Association,
Washington, D. C.

Potash from Kelp in Southern California

BY H. L. GLAZE

At the present time the production of potash in the United States is receiving a great deal of attention from chemists and chemical engineers throughout the country. This is occasioned by the fact that the supply of the German article is cut off by the war in Europe. A number of natural sources of this necessary commodity have been experimented upon, but the one great natural source that seems to be receiving the greatest expenditure of time and money is the kelp of the Pacific Ocean.

There are at least four large interests now at work on the problem and from the immense amount of money being spent it would seem that some one of these must have solved the problem. It is, of course, impossible to learn the details of all the processes being tried, but a glimmering of the trend of the industry as gathered by one in touch with some of the work being done is as follows.

There have been several attempts to utilize the kelp during the last few years, several experimental plants having been built and tried out, but none of them seems to have been a commercial success. Perhaps the first of these was the Pacific Kelp Mulch Company of Terminal Island, Cal., operating a plant for several months, harvesting and cutting the kelp into small pieces, sacking the produce and selling it as a fertilizer. This scheme involved the paying of freight on an immense amount of water as it is a fact that kelp contains about 90 per cent, and little or no effort was made to dry it. The kelp was simply shipped to the farmers, who spread it upon the land and plowed it under.

Another company was formed to exploit kelp on a more scientific basis, about four years ago. This concern, which was financed by popular stock subscriptions, built an extensive plant at Cardiff by the Sea, Cal. They probably never produced any potash on a commercial scale and their efforts ended when their creditors took over their assets. This ill-fated venture was followed by the American Potash Company of Long Beach, Cal., which fell heir partially at least to the process and machinery of the Cardiff plant, and to the best of the writer's recollection some of the same men were connected with both concerns.

The plant of the American Potash Company consisted of a kelp harvester, storage bins, a drier, calcining furnaces and leaching tanks. The scheme of operations was approximately as follows: The kelp was harvested and cut into pieces about 6 in. long on the harvesting barge, it was then towed ashore on the barge and landed on the dock by means of a derrick and hay fork. The main storage consisted of bins, although a good deal of the material was piled on the ground, which seems to indicate that the capacity of the harvester exceeded that of the rest of the plant. From the storage bins the kelp was conveyed on a belt to the feeder of the drier which was of the rotary direct-heat type burning crude oil. Here the moisture content was brought down to about 10 per cent, and some was sold in this state as fertilizer and the remainder was burned

in reverberatory furnaces. The ash from these furnaces, which also burned oil, was leached with water and the soluble salts consisting largely of KCl and NaCl were separated out by fractional crystallization. This plant did not seem to be successful at the prices then obtainable for potash salts, although the promoters claimed that the capital available was not great enough to enlarge the plant to an economical size.

The foregoing attempt was followed by a plant in San Diego, Cal. This factory also used a drier of the direct-heat type and some other machinery. The proprietors are reputed to have taken out patents on a "deglutiniz-ing" agent which they mixed with the cut kelp, afterward grinding the mixture to a pulp and filtering off the liquid portion which was supposed to contain the potash. This liquid was evaporated to obtain the salts and the solid portions were dried and used as a fertilizer. These people also claimed to have discovered that if the whole kelp were fed into a drier and heated to such a point that it was partially burned or "seared" over, it would be converted into a much more valuable fertilizing product than if it were merely reduced to dryness. In spite of all this the process did not prove a success and the plant was finally leased by one of the present concerns as will be mentioned later.

Since the war started, the price of potash having gone up, two or three attempts were made to revive the old plants and also to dry kelp by the heat of the sun. The latter did not work out as the operation was necessarily carried on at tide water and the heavy fogs at night wet the kelp about as much as it was dried out in the day time. This brings us down to the present time and to a consideration of the great forces now at work on this source of potash.

About the first in the field during the recent revival was the American Products Company which started to do experimental work at Pasadena, Cal., and which later bought the effects of the American Potash Company and moved to the property of the latter at Long Beach. This company is being financed by Mr. George Simmons of the Simmons Hardware Company of St. Louis, Mo. Mr. Isaac Nailor is the chemist and originator of the process which the company is using. Considerable mystery surrounds the operations of this concern, but it was learned from Mr. Nailor that the principal product of his process would be a cellulose insulating compound for pliers and knife handles for soldiers' use in the field. He also mentioned that the cellulose that he could produce could be nitrated and used for explosives. The American Products Company has to date spent a great deal of money without seeming to have accomplished much. They built at an expense of about \$10,000 a harvesting barge that exceeded in size anything before attempted here. This barge had sickle blades like a mowing machine which would cut a swath 40 ft. wide and the depth of cut on the kelp was 6 ft. The kelp was to be elevated to two large macerating machines which were to reduce it to a pulp and in this condition it was to be conveyed to barges to be towed to the plant on shore. The machinery was to be driven with gasoline engines and an original system of propulsion and steering of the cutting barge was attempted. This harvesting machine was more or less of a failure and the report is now current that it has been dismantled and a new barge is being built along different lines.

The barges for carrying the kelp ashore were to have valves in the bottom and the plant was to have a marine railway to haul the barges out of the water at each trip. The macerated kelp was to be sluiced out of the barges by way of the valves in the bottom by the use of waste liquors from the reduction plant. These details are

about all that is publicly known of the Nailor process except that immense driers, evaporators, crystallizers and boilers are projected and the plant is being laid out to handle hundreds of tons per day of the raw material. Various patents have been applied for on the details of the process.

The significant thing about this project is that the potash will be a by-product of the manufacture of cellulose products. Incidentally it is understood that this process contemplates the heating of large bodies of material to a high temperature and under pressure in retorts. This company has done considerable work on a small scale and they seem to have satisfied themselves that they will be able to achieve their aim.

The second large experimenter to appear in the field was Swift & Company, the meat packers, who evidently need potash for their fertilizer products. Messrs. S. G. Smith and G. H. McCoy are the engineers in charge of the Swift kelp plant and Mr. Smith has been on the ground for several months collecting data and doing experimental work preparatory to the building of a plant. Swift & Company leased the small plant at San Diego mentioned above and have thoroughly satisfied themselves by a test of several months that they could make a satisfactory fertilizer material from kelp. This experimental plant or at least that portion of it used in the experiments consists of a wharf for landing the kelp from the cutting barge, a conveyor and a drier of the direct-heat type 54 in. in diameter and 35 ft. long. Swift & Company afterward added another drier unit 60 in. in diameter and 40 ft. long, the kelp being fed into the cold end of the first and larger drier and discharged into a conveyor carrying it to the hot end of the second and smaller drier from the cold end of which it was discharged with a moisture content of about 10 per cent. Crude oil was used as fuel and the drying was carried on without carbonizing the product to any great extent. The product was then ground in a swing hammer mill, sacked and shipped to the fertilizer factory in the east.

The product from this plant contains the whole body of the kelp, the potash, amounting to about 15 per cent by weight, and about 10 per cent water. A slight amount of nitrogen is also claimed. This material is used to make up the potash requirement of the fertilizer and the cellulose and other inert constituents are figured as filler the same as tankage. At the present price of potash it will be seen that this dried kelp is a very valuable article and even if it did not run over 10 per cent potash, it would stand shipping to the company's Eastern fertilizer plants. Swift & Company evidently found it to be a profitable venture, as they are now building a larger plant at San Diego, Cal.

This new plant will contain ten direct-heat driers 60 in. in diameter by 40 ft. long, burning crude oil, and probably working in series the same as those in the experimental plant. The plant is being housed in steel and corrugated iron buildings. It will be electrically driven by alternating-current motors with one motor to each pair of driers. The dried kelp will be ground before shipment East. It is estimated that this plant will have a capacity in excess of 200 tons of wet kelp per twenty-four hours, giving about twenty tons per day of dried material containing from 10 to 15 per cent KCl. This company also designed and built their own kelp-harvesting machine which works on the ordinary mower principle. They have purchased two scows and a tug for use in the work of gathering the kelp. Their factory will be located in the center of the water front of the city of San Diego on the Santa Fé Railroad and will be arranged to handle the output on an efficient basis. It is said that this plant will be permanent, if

it shows any success at all, even though after the war the price of foreign potash be reduced.

The Diamond Match Company is also in the field with a small plant at Long Beach, Cal. Very little is known of the intentions of this company except that they evidently need potash in their match factories and that they have been experimenting to some extent in the north. Mr. O. Z. Howard is the engineer in charge of the work. They have let contracts for several wooden buildings and it is known that they have bought three direct-heat driers in the East. It is rumored that the process to be used in this plant includes a freezing operation, but it is not known whether the potash will be the principal product or a by-product of the process.

The crowning achievement along the kelp potash lines will be the venture of the Hercules Powder Company at San Diego. This plant will be an immense structure with many buildings, acres of tanks and many tons of especially designed machinery and chemical apparatus. The construction work is in the hands of Charles C. Moore & Company of San Francisco, who have upward of 500 men working. Practically nothing is known of the Hercules process, but it must be to some extent similar to the Nailor process. If the reports may be believed this plant will turn out large quantities of nitro-cellulose from kelp and hundreds of tons of potash as a by-product. None of the details of the projected process is yet apparent, but it is known that several large driers have been purchased in the East and some of the buildings on paper look very much like nitrating houses. The writer has seen some of the drawings of this plant and as everything seems to be of the very best material and construction it must be that the engineers of the Hercules Powder Company have done lots of preliminary work in order to warrant such expenditure.

It would seem impossible that all of these new processes would prove failures. Therefore we may expect to see some new and more or less revolutionary or at least unexpected things occur in the cellulose and fertilizer industries in the next few months. Cellulose good enough for nitrating means practically pure cellulose and that means cellulose suitable for many purposes such as viscose, viscid, photographic films, celluloid, artificial silk, paper, etc.

The kelp beds of the Pacific have been investigated by the Department of Agriculture and one or two bulletins have been published. Very complete maps have been made of the various beds extending from Alaska to Mexico and there has been some talk of Federal regulation of the use of these beds.

There is an amazing diversity in the various statements published regarding the amount of potash, iodine and other constituents of the kelp and the writer has seen the weight of the wet kelp put all the way from fifteen to forty-five pounds per cubic foot. The moisture content is an equally variable quantity and to the best of my knowledge no data have been published as to the amount of cellulose contained, nor anything as to the nature of the glutinous part of the plant and its possible use. There seems to be here a very fertile field for research work and it will be interesting to observe the progress of the future work on this material.

Los Angeles, Cal.

The annual meeting of the American Electrochemical Society will be held in Washington, D. C., from Thursday to Saturday, April 27 to 29, 1916. Those members and guests who will go to the meeting from New York and like to travel in the special car or cars to be provided for that purpose on a Wednesday afternoon Pennsylvania Railroad train are requested to notify the secretary of the New York section, Mr. J. M. Muir, 239 West Thirty-ninth Street, New York.

The Glass Industry

Meeting of New York Section of Society of Chemical Industry

A symposium on the American glassware industry was held at a meeting of the New York Section of the Society of Chemical Industry at the Chemists' Club March 24. Preceding the presentation of the papers the annual election of officers for the coming year was held. The following officers were elected: JEROME ALEXANDER, chairman; PARKER C. McILHINEY, secretary. The new chairman presided at the meeting.

The first paper was on the "Development of Low-Expansion Glasses," by Dr. E. C. SULLIVAN, chief chemist of the Corning Glass Works, Corning, N. Y. Dr. Sullivan gave a very interesting description of the methods of testing glass and the strict specifications which must be met for certain purposes such as laboratory ware.

The chief difficulty that the manufacturer encounters in developing low-expansion glass is that as expansion of the glass decreases the fluidity also decreases. Boric oxide counteracts this tendency to some extent, but above a certain percentage it affects the stability. The method of testing the expansion of a piece of glass which is used by Dr. Sullivan is a method developed by Holborn and Day, using a water-jacketed electric furnace, with two totally reflecting prisms sighted on the ends of a piece of glass. The piece is heated to 350 to 400 deg. C, and the method is accurate to a few tenths of 1 per cent. Other tests described were those of placing a number of glass canes side by side in a vertical electric furnace and at the proper time dropping them through the sliding bottom of the furnace down into water. The tensile strength and modulus of elasticity are determined by the ordinary methods. The tendency to crystallize is determined by a method developed in Jena. The resistance to attack by reagents is determined by making beakers of the glass and heating them filled with distilled water or with the reagent in question at about 80 deg. for considerable time. The water is then tested for dissolved substances.

Dr. Sullivan then mentioned a glass which his company has developed having a very low coefficient of expansion (0.0000032), and which has consequently a great resistance to sudden changes of temperature. It is also very little soluble in water, acids or alkalies, and compares favorably with the best European resistance glass. Samples of the glass were shown. Some very interesting lantern slides of various tests made on this glass and of its application to baking dishes were shown. It was pointed out that radiation in baking dishes was really the paramount factor rather than conduction. Slides were shown of comparative tests made on baking in metal and glass dishes, which proved conclusively that the glass dishes attained a higher temperature in the same time than the metal dishes and were consequently more economical.

In reply to questions, Dr. Sullivan said they had encountered serious delays in making laboratory ware, but were now in a better position; he said that they had not taken up the manufacture of glass for vacuum apparatus and that he did not think they could compete with Europe on a duty-free basis, and as institutions obtain glassware duty-free it was suggested that something ought to be done to protect the American manufacturer.

The next paper was presented by Mr. S. R. SCHOLES of the Mellon Institute, Pittsburgh, and chemist of the H. C. Fry Glass Co., Rochester, Pa. Mr. Scholes said the art of glass-making had far outrun the science and there were many things that needed a scientific expla-

nation. He reviewed the history and development of glass-making in this country and then took up the manufacture of cut glass and tumblers. He gave a very interesting description with numerous lantern slides, showing the making of the pots, the furnaces and the melting process. The operations of gathering and pressing, selecting ware, cutting and polishing, blowing, pulling stems and foot-setting, and finishing blown ware, were described in considerable detail. Specimens of ware in the various stages of manufacture were shown.

Mr. Scholes then took up the chemistry involved in glass-making, especially the problem of decolorizing. The use of manganese was explained and a new theory advanced for its behavior in glass. The burning out was thought to be due to the formation of manganites or manganates; that is, to a chemical change rather than a physical one. Some substitutes suggested for manganese were nickel and selenium. Nickel has possibilities, but selenium offers great difficulties, and Mr. Scholes thought it unlikely that it would ever find much use as a decolorizer. He said the development of a perfect decolorizer was one of the greatest needs of the present-day glass making.

This paper brought out some very interesting discussion as to the theory of decolorization. It was pointed out that microscopical examination might yield some information as to the physical structure and that the change may be a physical rather than a chemical one as in the case of gold ruby glass. Another suggestion was made that the same ingredients as in the glass might be placed in aqueous solution and tested in that manner. The application of X-rays to coloring glass was discussed and a recently patented process was stated to make it possible to produce a color in decolorized glass to any desired depth under the surface or completely through glass 1 in. thick.

The last paper was presented by C. OSGOOD ANDREWS, special representative of the Plate Glass Manufacturers of America. Mr. Andrews first reviewed the history and development of glass-making and then gave a very interesting description of the manufacture of "glass we see through." The methods of making plate and window glass were described and general conditions governing the glass industry were cited. The paper was especially interesting in that it discussed the present status of the glass industry and pointed out that we were not obtaining any glass from abroad at the present time. American made glass was compared with foreign glass.

The meeting was well attended and a lively interest was shown in the glass industry. Adjournment was made at a late hour.

Meeting of New York Section of American Institute of Mining Engineers

A very interesting meeting of the New York Section of the American Institute of Mining Engineers was held at the Machinery Club on the evening of March 23. The meeting was preceded by a dinner, and was very well attended. Mr. Frank J. Sprague, member of the Naval Consulting Board, who was to talk on some phase of the naval problem, was unfortunately unable to be present, and in his place Past-President W. L. Saunders, also a member of the Naval Consulting Board, gave a very interesting talk in his genial manner on the work of the board, with especial reference to the sub-committee on organization. This was followed by an illustrated talk by Dr. Charles L. Reese of the Du Pont Powder Company on explosives. Dr. Reese's

address was very interesting and instructive, and the meeting was thoroughly enjoyed by all those who attended.

Spring Meeting of American Chemical Society

The fifty-second meeting of the American Chemical Society will be held at the University of Illinois, Urbana-Champaign, from Tuesday, April 18, to Friday, April 21, inclusive. General meetings will be held in the university auditorium, and meetings of divisions will be held in the Chemistry Building. In conjunction with the meeting the splendid new chemistry building of the University will be dedicated, and an exhibition of chemical products and apparatus will be held in the large first floor laboratories of the new building. The local section of the society invited the leading manufacturers of chemical products and apparatus to participate in this exhibition. A partial list of exhibitors is given further on.

The chairmen of the different local committees are Professors Edward Bartow, W. A. Noyes, C. W. Balke, C. G. Derick, D. M. McFarland, E. W. Washburn, S. W. Parr, G. D. Beal, H. L. Olin and Miss Isabel Bevier.

The following provisional program will give an idea of the plans for the Urbana meeting. The session Tuesday morning will be given up to presentation of some four important papers of general interest. Dr. G. H. A. Clowes, of the Gratwick Research Laboratory, has agreed to present for the first time the results of his extended research "On the Influence Exerted by Electrolytes on the Equilibrium of Emulsions, Jellies and Living Cells" (with demonstration). Three other papers will be announced in final program. Tuesday afternoon will be a general "get-together" excursion to parts of the university grounds. The points of interest to be seen are the model dairy, the annual spring floral display and floricultural greenhouses, the vegetable greenhouses, model dairy barns, and prize cattle exhibit in the new stock-judging pavilion. After a concert by the University of Illinois military band, a "get-acquainted" smoker will be held Tuesday evening.

On Wednesday morning there will be division sessions, while in the afternoon the dedication of the new chemistry building of the university will take place. Governor Edward J. Dunne of Illinois will preside, and addresses will be made by President Edmund J. James, Dr. W. R. Whitney and Dr. Alexander Smith. In the evening a banquet will be held at Masonic Temple.

On Thursday division meetings will be held and in the afternoon there will be excursions on the University campus. The points of interest will include the laboratories of mechanical, mining, hydraulic, electrical, railway, and ceramic engineering, the vivarium, the botany annex, and the activated sludge plant. On the evening of Thursday there will be two illustrated lectures, by Dr. Charles L. Parsons on the production of radium, and by Dr. Curtis F. Burnam on the use of radium in the treatment of cancer.

On invitation of the Commercial Club and manufacturers in Danville the society will go to Danville on Friday for the purpose of visiting the Hegeler Brothers' zinc smelter and sulphuric acid plant, the Western Brick Company's kilns, and the Three Rivers Coal Company's strip coal mine.

Special attention is called to this extension. The smelter of the Hegeler Zinc Company was built in 1908 and is one of the most modern and best arranged in the country. The capacity has recently been trebled. The smelter utilizes the fumes from roasting the zinc

ore. The brick and tile plant of the Western Brick Company is one of the largest in the country, and of especial interest are the open pit shale and coal mines furnishing material and fuel. The strip pit coal mine gives a splendid illustration of the location of coal. Usually a bed of coal a quarter to a half mile long and 50 to 100 ft. wide is exposed. Arrangements are being made for optional visits to other plants if the members desire.

The list of exhibitors registered prior to March 8, 1916, for the exposition of Chemical Products and Apparatus, to be held in connection with the convention, is as follows: Abbe Engineering Co., P. Blakiston's Son & Co., Celluloid Zapon Co., Central Scientific Co., Dearborn Chemical Co., Duriron Castings Co., Eimer & Amend, Elyria Enameled Products Co., Fairview Fluorspar Co., General Electric Co., Henry Holt & Co., International Instrument Co., Jeffrey Dewitt Co., Kimble-Durand Glass Co., Laboratory Supply Co., Leeds & Northrup, Lenz & Naumann, Libbey Glass Co., Longmans, Green & Co., Emil E. Lungwitz, Macbeth Evans Glass Co., Manhattan Rubber Co., McGraw-Hill Book Co., McIntosh Stereopticon Co., Metallurgical and Chemical Engineering, Mojonner Bros. Co., National Carbon Co., National Lead Co., Norton Co., Pfaudler Co., Schaeffer & Budenberg Mfg. Co., Schutte & Koerting Co., Scientific Materials Co., Sowers Mfg. Co., E. R. Squibb & Sons, Standard Calorimeter Co., Sweetland Filter Press Co., Thermal Syndicate Co., Thwing Instrument Co., Toch Bros., U. S. Bottlers Machinery Co., John Wiley & Sons.

Dr. Charles L. Parsons (Box 505, Washington, D. C.) is the secretary of the American Chemical Society.

The Western Metallurgical and Chemical Field

Alkali Deposits of California and Oregon

At the present time there are but few practical data obtainable relative to the great deposits of natural alkali situated in California and Oregon; but believing that some of the Western alkali lakes are likely to assume commercial importance, we are glad to present herewith some notes on the subject by Mr. THOMAS M. SKINNER, JR. In his opinion Owens Lake, Cal., and Summers, Abert and Alkali Lakes, Ore., offer the best opportunities for recovery of dissolved alkali salts. Fol-

	Owens Lake, Cal.	Summers Lake, Ore.
NaCl	39.51%	27.10%
Na ₂ CO ₃	41.34	43.91
NaHCO ₃	4.41	21.41
K ₂ CO ₃	2.21	3.63
Na ₂ SO ₄	12.66	2.21
SiO ₂	0.095	0.87
Fe ₂ O ₃ and Al ₂ O ₃	0.062	....
Total	99.687%	99.13%



OWENS LAKE, CALIFORNIA, LOOKING TOWARD SALINE VALLEY AND WHITE MOUNTAINS

lowing is an analysis of the solids contained in the waters of Owens and Summers Lakes:

The past year is the first time that practical steps have been taken on a large scale to effect a separation of potash from these waters. This was successfully done at Owens Lake, making a high-grade fertilizer salt from the spent waters obtained from the manufacture of soda ash. These spent waters, which were formerly wasted, contained 4.25 per cent potash which is now recovered as a valuable by-product.

Owens Lake is situated south of Mt. Whitney and northwest of Death Valley, Cal., being between one of the highest points above, and the lowest point below, sea-level in the United States. The lake is reached by the Southern Pacific railroad from either Los Angeles, Cal., or Reno, Nev. The Southern Sierra Power Co. has distributed electric power around three sides of the lake, and furnishes power at about 1½ cents per kilowatt-hour and light at 10 cents. The lake is 27 miles long and 23 miles wide, and is estimated to contain 4,000,000 tons of sodium carbonate alone, with proportionate amounts of the other salts shown in the analysis.

At Summers Lake, Ore., the water excels that of Owens Lake in some respects, but generally speaking is about the same. Abert Lake water is quite like that of Summers. Both are within 30 miles of Pleasant View, Ore., where the railroad connects with Reno, Nev. Alkali Lake has produced great quantities of crude sodium carbonate, but the distance from the railroad does not yet warrant the manufacture of products.

The most important alkali products constantly in demand on the Pacific coast which can be made from these waters are: Caustic soda, dense soda ash, light soda ash, bicarbonate of soda, silicate of soda, potash, sal soda (snowflake and monocrystal), table salt, and others.

About 5000 tons per year of dense soda ash is being produced at Owens Lake at a cost of \$6.15 per ton. At the present time the selling price is about \$21 per ton. This product is made partly by methods of recrystallization and partly by the direct furnacing of crude sodium carbonate, the latter being obtained by solar evaporation and fractional crystallization. Recrystallized dense soda ash costs about \$3 per ton more for manufacture than the other product, but is far superior to it for glass and paper manufacture. Considerable quantities of this high-grade material are used on the Pacific coast; and with the exception of the product from Owens Lake the entire supply is shipped to the coast from, or east of, Hutchinson, Kans. The Solvay company is the chief source of supply, making soda ash from sodium chloride by the Solvay process.

Caustic soda is a product now in great demand, bringing over \$100 per ton. It should be produced at Owens Lake for about \$21 per ton. Liquid caustic could be



POTASH AND SODA ASH VATS AT OWENS LAKE, CALIFORNIA. KEELER, CAL., IN DISTANCE

marketed in large quantities on the Pacific coast, if produced as near the market as either Owens or Summers lakes, since this form is preferred by such consumers as oil refiners, sugar manufacturers, meat packers, tanners, wool scourers, and in the dried fruit industry. Seven thousand tons of caustic soda is sold yearly in San Francisco alone.

Bicarbonate of soda can be made at about \$2.75 per ton, and at present prices will bring from \$12 to \$14. This article contains about 12 per cent moisture, but upon drying or heating to light soda ash it would bring about the same price as dense ash. Several Western concerns are now making a desirable product in the form of a washing soda by compounding light ash, bicarbonate of soda and borax.

Remarkable Tungsten Market

During the past year and a half we have become accustomed to spectacular prices for metals, but we believe that the case of tungsten surpasses anything relating to the common metals. There have been some unusual advances in price for certain chemicals, but among the ordinary metals in commercial demand tungsten holds the record for rapid and extreme increase in price. About the beginning of the war, and in fact for the year 1914, the price of tungsten averaged about \$6 per unit of 20 lb., basis of 60 per cent WO₃. For the week ending March 13, 1916, the price for 60 per cent concentrate was published at \$90 per unit; and owing to the competition between buyers and the active bidding for good material, \$100 and more was paid for the grade mentioned.

In Boulder County, Col., the greatest activity prevails. Mills are buying ore that in former times would not be worth mining, and are paying such prices for it that small producers are reaping phenomenal profits. Ore containing 3 per cent tungstic acid will bring \$16 per unit, or \$48 per ton; 7 per cent ore will bring \$40 per unit, or \$280 per ton, and so on up to \$90 per unit, or \$5400 per ton for 60 per cent concentrate. With ore at such prices and with a ready market at hand, there has been some difficulty in preventing theft of rich ore or concentrate, and the scene of "high-grading" in Colorado has been shifted temporarily from Cripple Creek to Boulder County. The future of the industry is highly speculative and uncertain. Opinion differs as to the effect on tungsten prices when the war ends. Some incline to the belief that the bottom will drop out of the market suddenly and that it will be difficult if not impossible to market the metal. Others think that while the price certainly will drop, it will still remain at a figure in excess of normal prices for preceding years.

Company Reports

During the year 1915 the Yukon Gold Co. acquired additional properties in California and Alaska, the estimated gross gold content being \$3,800,000 and the estimated net profit \$1,500,000. The seven Dawson dredges were operated for 88.1 per cent of the season of 147 days, mining 5,041,075 cu. yd. and producing \$2,456,597, or an average of 48.73 cents per cubic yard. The average cost, including depreciation, was 26.46 cents per cubic yard, which is less than the cost for 1914 by 1.16 cents. There was a reduction in value of the ground dredged amounting to 5.48 cents per cubic yard. During the season a total of 380,340 sq. yd., or 64.7 per cent of the ground handled, had to be thawed by steam. In the Iditarod the season was 196 days, and the dredge handled 926,956 cu. yd., producing gold to the value of \$845,998, an average of 91.3 cents per cubic yard. The average cost was 38.7 cents, which was lower by 11.5 cents than for 1914. Due to better dredging conditions and to the installation of sand elevators, this

dredge handled 4717 cu. yd. per day, a gain of 1216 yd. over the preceding season. The three California dredges handled 3,818,126 cu. yd. of gravel, yielding \$437,852. The average cost was 4.51 cents per cubic yard. By hydraulic operations the yardage mined amounted to 3,031,647 cu. yd., producing \$412,535 at a cost of \$243,247. The working cost was 7 cents per cubic yard. The water duty was 6.13 cu. yd. per miner's inch. The total profit for the year was \$2,121,031; deductions, \$1,036,081.

The Mary Murphy Gold Mining Co., Colorado, operated its milling plant throughout the year 1915 on a basis of 175 tons per day. The introduction of the flotation process is credited with a large part of the profit for the year. The cost of mining for the year, on the basis of 60,561 tons, was \$3.20 per ton as against \$3.08 for 1914 when 53,211 tons was mined. Milling cost per ton for 1915 was \$1.99; for 1914, \$1.96. The distributed milling cost for two years is as follows:

	Per Ton	
	1914	1915
Crushing mill, operating	\$0.30	\$0.26
53,012 tons 1914		
57,510 tons 1915		
Crushing mill, maintenance	0.07	0.07
Concentrating mill, operating	1.04	0.76
48,526 tons 1914		
55,830 tons 1915		
Concentrating mill, maintenance	0.20	0.20
Ore tests and experiments		0.01
Flotation work		0.13
Mill water supply		0.02
Tailing dams		0.12
Electrostatic mill, operating	4.90	3.08
(zinc middling only) 4060 tons 1914		
6013 tons 1915		
Electrostatic mill, maintenance	0.36	0.66
Electrostatic mill, royalty	0.75	0.75

The operating profit for the year, after providing for depreciation was \$220,415, due in great measure to the high price of zinc. About one-half the net profit, or \$110,000, has been set aside as a fund for acquiring new property.

Department Metallurgical Research Exhibit at San Francisco Exposition Now on Display at University of Utah

The exhibit of charts and cases of minerals displayed by the Metallurgical Research Department of the University of Utah at the Panama-Pacific International Exposition has arrived at the University and is being set up in the mining and metallurgy building. The exhibit consists of two large plate glass cases containing an educational series of Utah mineral and metallurgical specimens representing the consecutive steps in typical ore dressing and metallurgical processes, along with fifteen charts descriptive of the mining and metallurgical resources of the State of Utah.

Although available space is difficult to find in the crowded building, portions of the exhibit are being set up wherever any suitable space can be spared. This display material is directly in line with the work of the mining, metallurgy and metallurgical research departments, and will serve as a nucleus for a more comprehensive series of specimens and charts to illustrate the types of minerals and ores and the commercial products possible to obtain from the same that make up the very extensive mineral resources of the State.

It is the desire of those in charge of the departments to build up a mining and metallurgical museum somewhat after the nature of the exhibit by the U. S. Geological Survey that was on display in the Palace of Mines and Metallurgy at the San Francisco Exposition, entitled "Minerals and Their Uses." In the proposed collection will be shown the principal minerals and ores of Utah along with the product resulting from the commercial treatment of the same, together with the uses to which these minerals and products are applied.

The series will make an attractive and highly educational display and will serve to stimulate the ambitious student and interested visitor to lend his efforts toward developing the mineral resources of the State of Utah.

The Iron and Steel Market

The iron and steel market has grown less clearly defined. As to steel, it is largely sold to a standstill, while in pig iron everything hangs upon the question whether the large steel interests will be forced into the market to eke out their own supplies, which in most quarters are thought to be running short.

There have been two distinct developments in the past fortnight, distinct in themselves, but certainly furnishing no distinct indication of what the steel market is to do next. The first is that many buyers have lost interest in contracts for far forward delivery. They regard the prices so high that there would be a great risk in buying for the very late deliveries the mills would offer, and they find themselves unable to make a fair estimate of what their condition will be when such delivery period would arrive. It seems somewhat curious, after all, that such a feeling did not develop sooner. The condition of the market has changed in this respect, that whereas for months there were buyers ready to contract for much more steel for late delivery than the mills were willing to obligate themselves upon, it would now be difficult for the mills to sell large tonnages on open contracts, say, for the first half of 1917. It must be understood, of course, that the mills have been making no such effort. For months they have simply been picking out, of the business offered, such as they cared to accept.

Another new feature in the market is that some of the sellers of steel are unwilling to commit themselves that this price or that price is their minimum quotation. It does not appear that they have weakened in price, but rather that they quote higher and higher prices week by week but in the spirit that they do not wish to be placed on record that these higher prices are the minimum they would accept. The only explanation at all acceptable for the taking of this position is that the mills wish to curtail as far as they can the embarrassment that faces them whenever the time comes that they will have occasion to solicit business again. If they are not committed now to definite prices, then when they quote a certain price later there will be less occasion for the customer to regard the price as a cut from an established basis. While there is no doubt that present prices are so high as to make it impossible for some buyers to take hold, it does not appear that the mills are modifying prices according to the ability of consumers to pay. It rather seems that there is a growing feeling towards "preparedness" for the inevitable reaction. The mills are by no means a unit on anything, however. Some have "called in their salesmen" long ago, because they did not want business. Others, perhaps the more enterprising, have instructed their salesmen to make their usual rounds with the greatest fidelity, though they do not want orders, the idea being that the reappearance of a salesman, after a long absence, would naturally be construed as evidence that the market had weakened.

The pressure for steel has increased further, and this is indicated by higher prices being bid for prompt shipment. The large mills realize that their prices have advanced far beyond levels they could expect to maintain indefinitely and are, therefore, interested in obtaining such prices as can be secured. If they book less forward business, they stand to be able to work up to the point of making earlier deliveries, and thus, in

a sense, obtaining premium prices for prompt shipment if the markets hold strong long enough. As to the great bulk of their tonnage, the steel mills are sold up through the year, but it is probable that earlier deliveries can be arranged with certain buyers, upon occasion, than is generally admitted.

Pig Iron

The market as a whole has been less active the past fortnight than in the early part of March, but the undertone appears very strong indeed. The merchant furnaces are very well sold up and there is no indication that production can be materially increased. Meanwhile stocks of pig iron are diminishing and the steel works are increasing their capacity. It is thought in many quarters they will be forced into the market shortly, and the general view is that if such is really the case the pig iron market will advance very sharply. There is ample room for an advance, of course, since finished and unfinished steel have advanced on this movement about \$25 a ton, while pig iron has advanced only \$5 to \$6. Rebeca furnace at Kittanning, Pa., under lease to the Jones & Laughlin Steel Company since last October for the manufacture of ferromanganese, is to pass to the control of the owners at the expiration of the lease. The stack will be blown out for relining about May 1, to be blown in again about July 1 on basic iron. A deal has been effected for 100,000 tons of iron ore, 5000 tons of basic iron a month for ten months being furnished the seller of the ore. We quote: No. 2 foundry, delivered Philadelphia, \$19.75 to \$20.25; f.o.b. furnace, Buffalo, \$19 to \$19.50; delivered Cleveland, \$19; f.o.b. furnace, Chicago, \$19 to \$19.50; f.o.b. Birmingham, \$15 to \$15.50; f.o.b. valley furnaces, 95 cents higher delivered Pittsburgh; Bessemer, \$21 to \$21.50; basic, foundry and malleable, \$18.50 to \$19; gray forge, \$18 to \$18.50. Ferromanganese on contract is held at \$175, delivery being far in the future, chiefly 1917, while prompt lots have brought up to \$400 in a very excited and irregular market.

Steel

The market for unfinished steel continues very narrow so far as transactions go, there being only odd lots developing from time to time. It is thought a large tonnage of billets could be sold if desirable deliveries could be offered. We quote, practically nominal, \$45 for Bessemer or open-hearth billets or sheet bars. Rods are about \$60, but are difficult to secure at any price.

Finished Steel

It appears that there was some talk of putting up the price of rails, which have not changed, as to Bessemer, since February, 1901, but sales of over half a million tons have been made for 1917 delivery, setting at rest the rumors. Prices for forward delivery of all descriptions of finished steel continue to show an advancing tendency, and in steel bars and plates the premiums for prompt shipment have increased further. Regular prices given below are f.o.b. Pittsburgh, unless otherwise noted, the lower prices where a range is given being for delivery at mill convenience, the higher being for shipment within a few weeks.

Rails, standard sections, 1.25c. for Bessemer, 1.34c. for open-hearth, f. o. b. mill, except Colorado.

Plates, tank quality, 2.60c. to 4.00c.

Structural shapes, 2.50c.

Steel bars and bands, 2.50c., base; hoops, 2.75c., base.

Iron bars, Philadelphia, 2.559c.; Chicago, 2.15c.; Pittsburgh, 2.40c. to 2.50c.

Plain wire, 2.25c., base; wire nails, 2.40c., base; galvanized wire, 2.95c.; painted barb wire, 2.55c.; galvanized barb wire, 3.25c.

Non-Ferrous Metal Market

Tuesday, March 28.—The outstanding feature of the market is the strong situation in lead and the high prices being asked for spot and future deliveries by independents. Silver has also risen to the highest price in over two years. Other metals are substantially unchanged.

Copper.—The copper market has been quiet during the last two weeks and has fluctuated within very narrow limits. There has been very little buying. Offerings have been freer lately and there appears to be enough copper for sale to take care of any probable demands for the next two months. The market is firm, however, and there is no indication of any depression in prices. Spot electrolytic and lake are quoted at 27½ to 27½ cents. April and May are quoted at 27 cents, and June and July at 26½ cents.

Tin.—The tin market has been somewhat relieved since the middle of March, owing to arrivals coming in at a faster rate. During the first half of March only 343 tons of tin arrived, and this is small compared with an average consumption of 2000 tons during this time. The demand since the middle of the month has been light, however, and as more tin was coming in, sellers shaded the price somewhat. This did not stimulate buying, however, and the price dropped to 50 cents for spot Straits tin on March 21. Since that time the price has remained steady at 49.50 to 50 cents, and the market appears to be firm, although very uncertain.

Lead.—On March 14, the Trust advanced the price of lead to 7.00 spot, New York. Lead is scarce and very hard to obtain, and while the Trust still holds to the price of 7 cents, independents are asking 7¼ to 8¼ cents and very little trading has been done owing to the small offerings. April deliveries are quoted at 8 to 8¼ cents by independents.

Spelter.—The demand for spelter, which was at a very low ebb during the first half of March, improved considerably for a few days, beginning at about March 15, and forced the price of about 18 cents for prompt western shipment. This activity was not sustained and the market has since become dull again, although the price still remains 17.60 for spot. Early deliveries are not freely offered, and the following prices are quoted at New York by the American Daily Metal Market, April, 17¼c.; May, 16¾c.; June, 16¼c.

Other Metals.—Aluminium remains in its strong position and is quoted at 60 cents. There has been very little change in the antimony situation and 45 cents is asked for both American, and Chinese and Japanese spot deliveries. Silver has risen to 60¾ cents and is now at the highest price since October, 1913. The falling off in Mexican production and a larger foreign demand are thought to be the cause for this advance. Platinum is quoted at \$88 per ounce and quicksilver at \$200 per flask.

A Proposed Plant for the Fixation of Atmospheric Nitrogen

Mr. Pierre S. du Pont, president of the E. I. du Pont de Nemours Powder Company, has addressed the following letter to Secretary of War Baker:

WILMINGTON, DEL., March 26, 1916.

Hon. Newton D. Baker, Secretary of War, War Department, Washington, D. C.

My Dear Sir: On frequent occasions during recent years General Crozier has called our attention to the menace involved by our dependence on foreign nations for our raw materials for nitric acid supply, this commodity being absolutely essential in the manufacture of smokeless powder and other explosives and in great demand as an essential in the manufacture of fertilizers. Several years ago the fixation

of nitrogen from the air by the use of the electric arc was found practicable abroad, and, with a view of implanting the industry in this country (solving our problem here at home), the du Pont Company sent a corps of its experts to Europe to thoroughly investigate the various processes there employed. As a result of these investigations the du Pont Company purchased the right of one of the leading processes used abroad, which process is now established in Europe on a commercial basis on a large scale of production.

As you know, the process of securing nitric acid from the air requires large units of hydro-electric power at a very low cost. Coincident with our investigations abroad, we have been studying the possibilities for satisfactory hydro-electric power in the United States, and we find that, while the power physically exists, it is not available because of Governmental restrictions. I inclose herewith for your consideration a tentative draft of a bill which we believe will protect the public interest and justify the investment of the capital essential to the solution of this problem in the United States. You will note the bill we submit provides that the company "shall deliver to the United States for military or naval purposes all or any part of the output of nitric acid at a price which shall include such profit as the Secretary of War shall determine to be reasonable."

With the way made clear, the du Pont Company stands ready to negotiate a contract under which it will begin the construction of a plant under such units and magnitude as may be agreed upon between the Government and the du Pont Company, the du Pont Company to furnish the capital. Should you desire to confer with me on any of the phases of this question I will be pleased to make a trip to Washington at your pleasure.

Very truly yours,

PIERRE S. DU PONT, President.

The process in question is the Birkeland-Eyde process, operated on a large scale in Norway. It is reported that the proposed plant would involve an investment of \$20,000,000. It is further reported that the proposed bill provides for grants or leases of power and dam sites in navigable streams or in the public lands for fifty years, the rates for power to be regulated by State commissions or by the Secretary of War in States where there are no such commissions. At the end of the fifty-year term, the Government is to have the option of taking over the plant upon payment of a fair value of the property, with no allowance for franchise value.

New Zinc Plant in Oklahoma

Mr. J. E. Hildt of Tulsa, Okla., well known in Oklahoma as an organizer of banks and a former railroad engineer and contractor, is about to build a new zinc retort plant. He has associated with him a practical zinc smelter man of twenty-five years' experience and also three prominent engineering specialists. Contracts for material, machinery and supplies are now being placed. A refinery making strictly high-grade spelter analyzing 99.92 per cent is to be started at once with a large initial capacity, "deriving its 99 per cent metal from ores whose geologic individuality will give the metal the proper physical properties."

A specially refined "Prime Western" and "Brass Mill Special" freed from dross by a simple process will be made later. Particular attention will be paid to making the slabs of uniform composition.

The ore that will be used is to be largely commercially desirable flotation concentrates. In the fall a lead plant to extract the gold, silver, copper and lead values is contemplated; also an acid plant utilizing the sulphur in the ore to make a 98 per cent sulphuric acid for oil refineries is contemplated.

The Washington meeting of the American Electrochemical Society (April 27 to 29) promises to be highly interesting. Dr. A. S. Cushman is chairman of the local committee. Thirty-six papers will be read and discussed. The full program will be printed in our next issue.

The Operation of the Blast Furnace

BY J. E. JOHNSON, JR.

Slags

This subject has received an enormous amount of study at the hands both of practical men and scientists, but particularly the latter. Much experimental work has been done upon the subject, but in my opinion by far the larger part of this has been entirely wasted because the kind of information needed has not been appreciated. The purpose of the slag is twofold. First: to remove in a convenient form the impurities of the charge which come from all three of its components, the ore, the fuel, and the flux, and render them fusible so that they may be removed from the furnace at the lowest possible temperature, since as I have many time reiterated, this is the critical temperature of the furnace, and as was shown in the article on thermal principles this is the point about which everything else revolves. Second: the slag must remove the sulphur which is always present in mineral fuel, and sometimes in the ore, so as to prevent its entering the iron. In a narrow sense this is only a subdivision of the broader subject of removing the impurities of the charge, but in practice and in the habits of thought which grow up from the operation of the furnace, these two functions are separate and distinct, and we may well consider them so.

Let me make clear here what I think has too often been not clearly stated in dealing with this subject.

Our knowledge of it is 99 per cent empirical. It is true that good furnacemen calculate the slag they desire to produce with some care, but they do it not according to any scientific law, or on the basis of any chemical formula, but simply to produce a slag which they know from experience will produce the desired result to the best advantage. In some departments of metallurgy it may be necessary to figure the oxygen ratio of slags, that is to say, whether they are bisilicates, monosilicates, or sesquisilicates, but in the blast furnace we not only may, we must, ignore all these considerations if we desire successful results. This is an extreme case of that general law that in the furnace we deal not with a chemistry of definite proportions but with an infinitely varying balance between two or more, generally many, contending forces, and we would be unable to detect in the plotted curve of our results, if we could make one, the slightest sign of a cusp indicating a critical point, or sudden change in the characteristics of the slag. If we know that an increase of 2 per cent in the silica in the slag will make a certain change in its character then we may be perfectly sure that the next variation of 2 per cent will produce a change in the same direction, and of approximately the same amount.

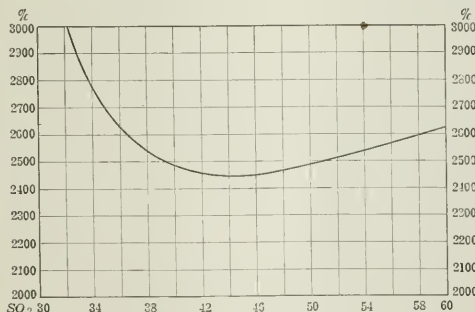


FIG. 1.—TENTATIVE CURVE OF FREE-RUNNING TEMPERATURE OF ACTUAL SLAGS BASED ON OBSERVATIONS AND PYROMETER READINGS IN PRACTICE

The sketch diagram, Fig. 1, gives the free-running temperatures of slags having alumina virtually constant at 12 to 15 per cent with silica ranging from 33 to 60 per cent. This is not intended to be accurate, for unfortunately I have not the data to make it so, but represents the results of much observation and many hundred pyrometer readings on actual slags throughout the range mentioned.

In charcoal practice we have ordinarily no sulphur to consider. That contained in the fuel is very slight, probably well under a tenth of 1 per cent, and since the great advantage of charcoal as a fuel is its freedom from sulphur, and since it is possible to obtain ores and fluxes quite free from that impurity, such furnaces are commonly operated only with such materials, and under ordinary circumstances should never be operated in any other way.

In this case then we have to consider only the production of a slag with the lowest possible melting point to permit its removal from the furnace, so as to have the lowest critical temperature, and as we have already seen, this is the reason that charcoal furnaces are able to run not only with a smaller weight of fuel per ton of iron, but with a fuel only containing about three-fourths as much fixed carbon as is contained in coke. In charcoal furnaces then we are free to use virtually any slag which will accomplish our purpose best, or briefly, that which is the most fusible in the sense of having not the lowest melting but the lowest free-running temperature, and I have used slags which ran all the way from below 40 per cent silica up to almost 60 per cent in that element.

No refined means of measuring the fluidity of these slags was at hand, but observations were made with a pyrometer, and by eye, and as a result of long experience it was found that both of these extreme slags were less fusible than a slag ranging from 46 to 49 per cent silica, as indicated by Fig. 1. Accordingly in running for low-silicon iron a slag of the latter kind was used, but when high-silicon iron was desired a more siliceous slag was used, both because its hold on the silica was weaker, and therefore the latter could be more easily reduced and thrown into the iron, and because its free-running temperature was higher and therefore gave the somewhat higher temperature necessary to force the desired silicon into the iron. By both these means, therefore, we facilitated the introduction of the silicon into the iron with the least excess of fuel over that required for low silicon.

Turning now to coke furnace slags we have an altogether different condition. The sulphur in the fuel varies from about 0.3 per cent or lower in very exceptional cases up to 1½ per cent or 2 per cent in some cases, and in abnormally bad cases even higher than this, even up to 3 per cent. On the basis of a ton of coke to make a ton of iron this means in the average case that sulphur to the amount of about 1 per cent of the iron is present in the charge, and to obtain a merchantable product we must eliminate this at least to 1/20 of 1 per cent, leaving the sulphur in the iron 0.05 per cent or under, therefore 95 per cent of the sulphur must be eliminated. To accomplish this we have two principal means both of which are accomplished simultaneously by one charge in the burden. We must increase the bases, generally the lime, in the charge, over what we use in charcoal practice.

The lime divides itself between the silica and the sulphur according to some law which has never been worked out, but in general the more basic the slag the more ready it is to satisfy itself with sulphur, and increasing its basicity has the effect also of increasing its fusion temperature; and this, by increasing the reducing action of the furnace, exerts a more powerful ac-

tion on the lime to reduce it to calcium sulphide, and thereby further increases its activity for desulphurization. But here we work under very different conditions from those which prevail in charcoal practice, because we come now to the fact that the change in fusibility of the slag toward the two ends of the range mentioned is very different, due to the fact that some slags are "short" and lacking in viscosity, like water or mercury or light oils, whereas others have a long viscous range like molasses or tar. They begin to soften and are no longer solid at temperatures far below those at which they can in any proper sense be called liquid and become liquid far below the temperature at which they become free-running.

The limey slags in a general way belong in the former class, whereas the silicious slags belong in the lat-

ter class. To illustrate this; if a limey slag be poured from a hand ladle it falls in little round pellets, almost like shot, which are individual drops when they strike the ground and when still red hot, whereas a silicious slag under the same conditions does not produce pellets but long strings, or if a little puddle of it be poured this will remain connected with the ladle by a string, and even when it is apparently almost cold this string can be drawn out like glass to great lengths.

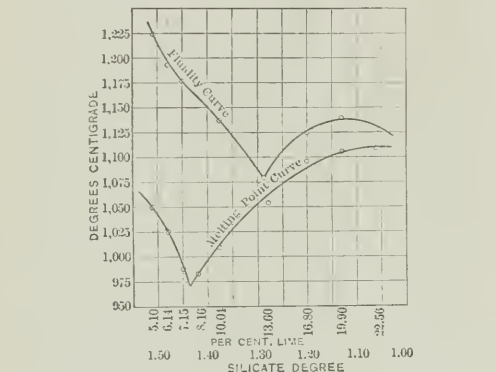


FIG. 2—MELTING-POINT CURVE—FLUIDITY CURVE

ter class. To illustrate this; if a limey slag be poured from a hand ladle it falls in little round pellets, almost like shot, which are individual drops when they strike the ground and when still red hot, whereas a silicious slag under the same conditions does not produce pellets but long strings, or if a little puddle of it be poured this will remain connected with the ladle by a string, and even when it is apparently almost cold this string can be drawn out like glass to great lengths.

This is probably one of the most important facts of furnace operation. For as has been so often reiterated, the important point is the free-running temperature of the slag, and with a limey slag it is only a few degrees from its softening point to the point where it runs freely, whereas with a silicious slag on the other hand this range is 200 or 300 deg. Although some work has been done along this line, exact data in regard to iron blast furnace slags on this basis have never been published, but Professor Fulton of the Case School of Applied Science published before the American Institute of Mining Engineers in 1912, a paper on "Copper Blast Furnace Slags," in which this point was well brought out, and from which Figs. 2 and 3 are reproduced. It will be clearly seen that the range between the free-running temperature shown by the upper line and the softening temperature shown by the lower one varies enormously. It is this fact which has done so much to minimize the value of investigations by scientists on this subject.

It is comparatively easy by making slag-forming materials into cones and observing the point at which the tip of the cone begins to deform to determine their softening point, but it is exceedingly difficult to determine their free-running temperature. The suggestion

of W. McA. Johnson to do this by timing the discharge of a given weight of slag at different temperatures through a standard-size hole in the bottom of the crucible containing it, is the best of which I have knowledge. I have suggested as a method of standardizing the orifice that the free-running temperature of an actual slag be taken at the furnace, and then that size of the orifice determined by experiment through which a given quantity of this slag at this temperature would run in a given time. The temperature at which any other slag would run through the same orifice in the same time would be its free-running temperature. It seems lamentable that with the facilities for doing this work possessed by modern colleges and universities, nothing has ever been done along this line, although it would go further than anything else to solve the practical problems of blast furnace operation.

The difference between coke and charcoal practice consists not only in the fact that the critical temperature in the latter is lower, but also in the fact of almost equal importance that in charcoal slags we are free to choose the flat range along the bottom of the curve of Fig. 1, and a variation either way does not affect the operation of the furnace very materially. But to secure the desulphurization required with low-silicon coke irons a ratio of lime to silica of about one and a half to one is necessary which is reached at approximately 34 per cent silica. It will be seen that this is on a decidedly steep portion of the curve; the result is that a slight change in the ratio of the lime to the silica has a great influence.

If the silica rise to 37 per cent, the ratio of lime to silica is only 1.35 to 1 and we are likely to have insufficient desulphurization, which in plain language means high sulphur or generally an unmerchantable product, while if the silica fall to 32 per cent, the critical temperature rises on the basis of this sketch diagram about 250 deg. Fahr., with a very serious effect on the operation of the furnace because we have not only the increased critical temperature and the consequent rapid diminution of hearth heat as shown by the chart in the article on thermal principles, but we have a decided increase in the amount of slag to be melted.

If the silica be reduced from 34 per cent to 32 per cent by increasing the lime, this involves an increase of 6 per cent in the total volume of the slag, and the increased hearth heat required for this added to the diminution of hearth heat produced per pound of fuel by the increase in the critical temperature quickly uses up any reserve of heat the furnace may have.

Failing sufficient hearth heat, the slag is no longer heated to its free-running temperature but becomes stiff and inactive; the iron is unable to free itself from the slag and heavy losses of iron occur, while on ac-

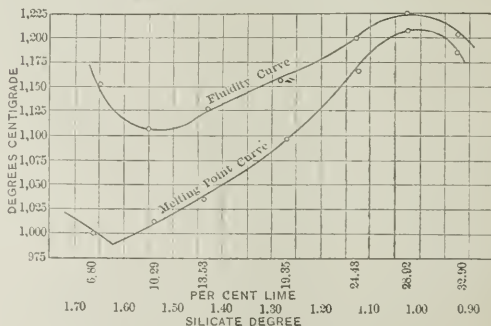


FIG. 3—MELTING-POINT CURVE—FLUIDITY CURVE

count of its lack of fluidity the slag is unable to desulphurize the iron, in which therefore the sulphur rises not infrequently to several times the permissible limits and the iron thereby becomes entirely unmerchantable. If this condition endures for more than a short time without obtaining relief from additional fuel or additional blast-heat the slag is likely to become so stiff that it can no longer be withdrawn from the furnace and the interruption to operation which results may last from twelve hours to many days.

Before this chain of events was thoroughly understood, and especially before it was realized that if the percentage of lime exceeded a certain amount, the desulphurization became worse and not better, because the stiffness of the slag more than outweighed its greater basicity, furnaces were frequently "lime set," that is, reached the point where the slag became nearly or quite infusible, and freezing up around the walls of the furnace prevented the iron from being withdrawn on one hand, and the ingress of the blast on the other. Stopping the supply of blast resulted in stopping the combustion of the coke and the generation of heat; this, of course, quickly exaggerated a condition already very serious and the furnace became entirely frozen up. In more than one case when the furnace was watered down preliminary to shoveling out, the quantity of lime in the hearth under these conditions was so great that it burst the structure. Many such cases have occurred in quite recent years and even down to the present time furnaces not infrequently come perilously close at least to the early stages of this condition.

It will be seen, therefore, that a coke furnace must be driven along a narrow path like that on the side of the mountain. If we deviate from the course on the upper side our progress is stopped and damage may result. If we go too far the other way we plunge to destruction at a rapid rate.

The elements with which we have so far dealt are particularly the lime and silica, the latter being the principal impurity, as well as the most acid in its action, which we have to flux out, and the former the base by which this acid is both neutralized and fluxed. The sulphur, as pointed out in the article on chemical principles, is present as calcium sulphide, a neutral substance, and not to be regarded either as an acid or a base. We have, however, other ingredients to consider, of which by far the most important in quantity and effect is alumina.

MAGNESIA AND ALUMINA

The effect of alumina has been a matter of vigorous dispute. Many furnacemen have been accustomed to consider it as an acid, and adding it to the silica, to consider the two jointly as "total acids." A few, on the other hand, have claimed that alumina, being the oxide of a metal, was necessarily a base, and as such have added some portion of it to the lime and magnesia.

Considering these opposite contentions, I began to believe a good many years ago that it was neither one, but acted only as a neutral addition, affecting the physical condition of the slag, but not affecting its viscosity or acidity to any important degree. This view was set forth by me in a paper before the American Institute of Mining Engineers in 1912, part of which is quoted as follows:

We may as well dismiss the obscurity which comes from the introduction of oxygen-ratios and other abstruse theoretical considerations, and admit frankly that experiment on the furnace itself is the only safe foundation for practice or for a useful theory.

I am moved to lay stress on this point, because in years past I was greatly puzzled and befogged by some

of the older school of furnacemen, who emphasized the mysterious nature and difficulty of making slag calculations, the fact being that, given the materials to be used and the slag to be produced, the college student who could not be taught in a day to make the calculations would have a poor chance of ultimate usefulness. The omission or concealment of the fact that the slag to be produced was known only by experiment and experience with the furnace itself caused my mystification, and I therefore emphasize it here.

The object to be sought may be briefly stated as follows:

Given the materials to be used and the kind of iron to be made, to ascertain the slag which will produce the results with the least cost for coke and for flux and will permit the greatest output. The three desiderata come in the order given.

We may in this discussion omit consideration of charcoal practice because the slag question is of minimum importance in that field, and the field itself is of minimum importance in the iron industry. Also because of my complete ignorance of that practice. (This paper was written three years ago, but has remained unpublished until now. It so happens that in the interval I have had extensive experience with charcoal-iron slags, but it is not considered desirable to introduce a consideration of that subject into this paper, because in the absence of the necessity for desulphurization the problems offered by charcoal slags are totally different from those of coke slags. In a general way, however, it may not be amiss to state that observation of charcoal slags has confirmed the position taken in this paper.)

Coming then to normal coke practice, and remembering that generally the lowest fuel consumption is obtained with the lowest critical temperature, the object desired may be stated more definitely as the production of the most fusible slag that will give the necessary desulphurization of the iron. This statement is, perhaps, subject to certain limitations from the fact that there are circumstances in which it is necessary to raise the critical temperature in order to enable the iron to absorb a large quantity of silicon.

The desulphurization effect of the slag is proportional, not only to its basicity, but also to its fluidity in an almost equal degree, so that while increased lime *per se* has a desulphurizing influence, this is to an increasing extent neutralized, and finally reversed completely, by its decreased physical activity.

This is well shown in basic practice, in which the highest sulphur iron is made, not with deficient lime but with an excess (due to a change in ore or the like) so great that the heat available is unable to bring the very refractory slag to the free-running condition necessary for proper desulphurization.

In further illustration of the point, there are two distinct methods of making this kind of iron. The first consists in running on a very calcareous slag, with which the silicon in the iron is kept down by the basicity of the slag in spite of the high temperature necessary to keep the latter fluid. The second consists in maintaining a slag of only moderate basicity and much lower fusion temperature, and keeping down the silicon by carrying a heavy ore-burden, which, of course, can easily be done with the lower critical temperature.

Furnaces running on the first plan always require more coke for basic than for foundry iron, while those running on the second plan use less than for foundry iron.

It seems to me practically certain, therefore, that there is a considerable range of lime content in the slag for given conditions, in which the desulphurization of

the iron is not appreciably affected, while the coke consumption necessarily rises with the increase in the fusion temperature consequent on the higher lime ratio, as well as the increased slag volume.

In all theoretical slag calculations the quantity of magnesia is multiplied by 1.4 to put it on the same basis as the lime, which, from the point of view of the oxygen ratio and molecular weights, is perfectly correct. Practically, however, this does not work out. Furnacemen using a limestone with a variable content of magnesia have told me that careful observation had failed to show any difference whatever on the furnace, whether the magnesia was high or low, and I have seen a furnace using half calcite and half dolomite, the calcite being relatively impure and the dolomite very pure, put onto all dolomite, which should have made the slag excessively basic, on the basis of molecular weight, but which, as a matter of fact, showed no observable change.

The truth seems to be that magnesia is less active chemically than lime in about the same proportion that its molecular weight is less.

An interesting proof of its small chemical activity is supplied by the manufacture of caustic soda from the carbonate. Quicklime is added to the carbonate solution, and takes up the carbon dioxide from the soda; for this purpose magnesia is found to be perfectly inert and worthless. Sir Lowthian Bell's opinion that magnesia was so inert as to be useless for the removal of sulphur in the blast furnace is well known, but this opinion is no more borne out by practice than that giving it a greater value than lime, the truth appearing to be that for furnace purposes, in all ordinary proportions, one is about as effective as the other.

It is very necessary, however, to recognize that the addition of a certain amount of magnesia has a marked effect in lowering the fusion temperature of the slag, and is therefore of great use where calcareous slags are required, particularly in the manufacture of basic iron.

For practical purposes lime and magnesia may be considered as being of equal value, and hereafter in this paper "lime" will be used to mean the sum of lime and magnesia.

THE EFFECT OF ALUMINA

The foregoing portion of this paper contains nothing essentially new, and is intended as an introduction to the remaining portion, the substance of which seems to have been unknown to most of the furnacemen with whom I have discussed the subject.

The effect of alumina has been the subject of much discussion; some regard it as an acid, others as a base, while a few declare it can be made to act as a base or an acid almost at will.

It has seemed to me that under such circumstances the probability was that its action was neither acid nor basic, but was perfectly neutral, simply a diluent affecting the viscosity of the slag to some extent, but, with a given ratio of lime to silica, not affecting its chemical nature at all.*

For several years the range of alumina in slag of which I had knowledge was so limited that I could not prove this contention, but very recently a furnaceman gave me complete information of a remarkable series of experiments he had carried out, in which the alumina

in the slag had been so high as 39.5 per cent with silica as low as 21 per cent on individual flushes, and averaging for an entire day SiO_2 , 24.7; Al_2O_3 , 36.0 per cent.

The iron made was good Bessemer iron, about 2 per cent of silicon, with sulphur about 0.023 per cent.

With this let us compare standard Lake-ore slag on basic iron running about Al_2O_3 , 13.5; SiO_2 , 33 per cent, and Virginia slag on the same iron, Al_2O_3 , 6.5; SiO_2 , 36 per cent.

It is unfortunate that the experimental run was on Bessemer instead of basic iron. The records of other days, which show basic iron made, are not so complete, but they indicate only a small difference in the slag, that shown, of course, being an increase in lime.

The coke consumption of this slag was not materially different from what it was in standard practice; the slags were free-flowing, and did not have a noticeably higher fusion temperature than ordinary.

Here, then, we have three cases, in all of which the coke is of about the same sulphur content, the desulphurization of the iron is the same, the coke consumption is no more different than would be accounted for by the different kinds of ore. The only difference of importance is the silicon in the iron, which is not sufficient to require a very great change in the slag composition. We will refer to this condition later.

The amount of lime in these slags can be determined by subtraction, but it is necessary to remember that there is a small quantity of neutral material, CaS , FeO , MnO , etc., which may be taken at 3.5 per cent in all cases as a close approximation to good practice. Following this procedure, the results shown in the first four columns of Table I are obtained:

TABLE I—COMPOSITION OF SLAGS.

	1	2	3	4	5	6	7
	Al_2O_3	SiO_2	CaO by Difference	Neutral Substances	$\text{Al}_2\text{O}_3 + \text{SiO}_2$	Ratio $\text{CaO} + \text{Al}_2\text{O}_3$	Ratio CaO
	per Cent	per Cent	per Cent	per Cent		SiO_2	SiO_2
Virginia practice	6.5	36.0	54.0	3.5	1.27	1.68	1.50
Lake-Ore practice	13.5	33.0	50.0	3.5	1.05	1.92	1.51
Special experiment	36.0	24.7	36.8	3.5	0.59	2.90	1.44

Columns 5 and 6 present the ratios of lime to silica + alumina, and lime + alumina to silica. These ratios change from 1.27 to 0.59 in the first case and from 1.68 to 2.90 in the second case.

No one can hope to show any relations between these ratios that can bear in any intelligible way on the variation of the alumina content.

Column 7, however, shows the ratio of the lime to the silica, which is virtually a constant throughout. The result in the experiment is the lowest, and corresponds to the higher silicon in the iron.

If the lime were increased in this latter case about 5 per cent of its own weight, this slag would then have identically the same ratio as the others, and would be just about as much "limier" as would permit the production of basic iron by the addition of a little more burden.

It may be claimed in opposition that the analyses chosen as representative of Virginia and Lake-ore practice have been taken with the object of showing the result desired rather than representing the typical slags. For the Virginia practice this certainly is not true, and if there be any error in the slag-analysis for Lake ore, I do not know how to better it. Certainly no correction that could be made would fail to leave the lime-silica ratio infinitely nearer a constant than either of the others.

It may be well to reiterate here that such a comparison is only useful in the case of furnaces on a comparable basis in other respects; that is to say, working for the same degree of desulphurization and the same sili-

*This conception of a given constituent affecting the physical but not the chemical properties of slag, in which two kinds of properties are so closely interwoven, is difficult at first sight, but I have illustrated it for myself as follows: If we had an ordinary acid, such as hydrochloric acid, in one beaker, and a solution of caustic alkali in another, we could mix the two in any proportions and each addition of one or the other would result in a corresponding change in the acidity or basicity of the resultant solution, but if we added a considerable quantity of molasses, we would alter its viscosity and its "free-running temperature" without affecting its chemical properties in any way. The illustration is a homely one, but in my opinion the case is precisely parallel to that of slags.

con, and using materials of about the same sulphur content.

The question of the slag volume also enters here, and the question whether a given slag volume is as efficacious in the removal of sulphur when the alumina is high as when it is low. We know that if the slag exceeds a certain content of sulphur in ordinary practice, the desulphurization of iron will be incomplete, and if the alumina be simply a diluent, the effectiveness of the slag might be diminished in proportion as the percentage of the alumina rose.

In spite of this theoretical consideration, the sulphur in the slags in the high-alumina experiments mentioned ran about 1.75 per cent with perfectly satisfactory desulphurization, while the relative slag volume was little, if any, higher with alumina approaching 40 per cent than with normal alumina.

The decreasing grade of the ores available must result in the increasing use of many ores higher in alumina than those of present practice. If the laws governing its action are not known bad results are bound to follow.

A furnaceman recently told me of a case in which the alumina had been regarded as an acid, and the slag had been calculated to give the same ratio of lime to silica + alumina as in standard practice, with the result that the furnace had been badly "bunged up" with lime.

In conclusion, it seems worth while to point out that the increased viscosity accompanying high alumina may be of benefit in making foundry iron. This was a subject to which both Mr. Frantz and I independently had given some consideration for several years.

That iron will not take up much silicon except at a relatively high temperature is well known, and as its melting temperature is relatively low, its tendency is to run down out of the region in which it can absorb silicon into the crucible.

The fusion temperature of slag is much higher than that of iron, and being more viscous, it acts as a retardant on the iron and delays its descent so that it can acquire the necessary temperature.

A too-fusible slag does not perform this function properly, and I have personally seen a case in which no reasonable reduction of burden would raise the silicon to ordinary foundry limits, but in which this was easily done by increasing the lime considerably beyond that necessary for desulphurization, in spite of the desilicizing influence of the more basic slag. For the same reason it is more difficult to make foundry iron when enough magnesia is present to increase the fluidity of the slag.

Now if alumina increases the viscosity of the slag without the accompanying desilicizing influence of the limier slags of the same free-running temperature, then the introduction of the silicon into the iron should be facilitated by high alumina.

It is six years since this paper was written though only three since it was published. In that interval all my experience has gone to confirm the opinions expressed therein, both as to the general effect of alumina and as to the entire possibility of using this element as a means of raising the free-running temperature of the slag without increasing its basicity, for the manufacture of high-silicon irons.

In very recent years a vast amount of work has been done under the auspices of the Carnegie Institution by G. A. Rankin, A. L. Day and E. S. Sheppard upon the melting points of the ternary system $\text{CaO}-\text{Al}_2\text{O}_3-\text{SiO}_2$. Through the courtesy of Mr. Rankin I have obtained a copy of his paper bearing that title published in the *American Journal of Science*, Vol. XXXIX, which gives the results of these investigations. These are plotted on the triaxial diagram, and from the plot an actual model was constructed, photographs of which, reproduced from Mr. Rankin's paper, are shown at Figs. 4, 5 and 6.

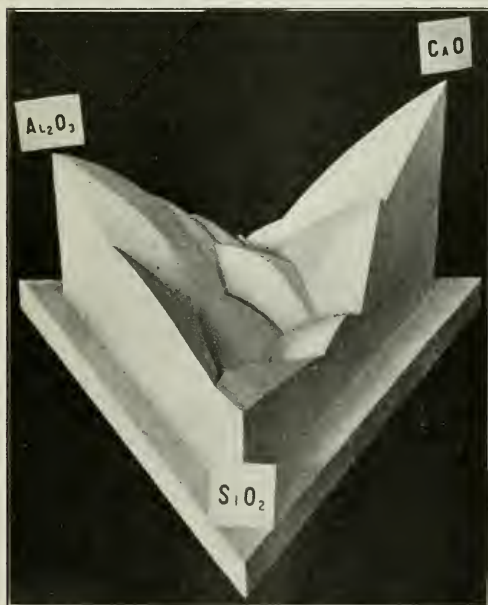


FIG. 4—PHOTOGRAPH OF SOLID MODEL OF CONCENTRATION-TEMPERATURE DIAGRAM OF TERNARY SYSTEM; SHOWING RELATION OF BINARY SYSTEMS $\text{CaO}-\text{SiO}_2$ AND $\text{Al}_2\text{O}_3-\text{SiO}_2$ TO THE TERNARY SYSTEM

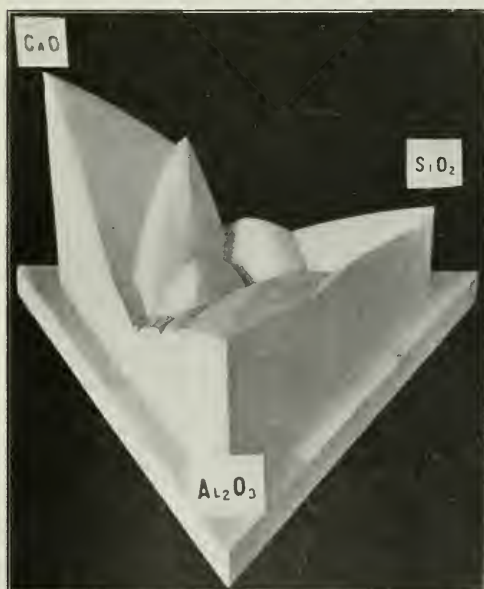


FIG. 5—PHOTOGRAPH OF SOLID MODEL, SHOWING RELATION OF BINARY SYSTEMS $\text{CaO}-\text{Al}_2\text{O}_3$ AND $\text{Al}_2\text{O}_3-\text{SiO}_2$ TO THE TERNARY SYSTEM

Before discussing these results it may be well to call attention to the characteristics of the triangular diagram. They are based upon the fact that in an equilateral triangle the sum of the perpendicular distances of an interior point from the three sides is a constant, and therefore the composition of any substance made up of three components may be graphically represented by the position of a point whose distances from the respective sides are represented by the percentages of the corresponding components. Each angle of the triangle represents one component unmixed with anything else. Any point on one side represents a compound consisting solely of the two materials represented by the two ends of that side without any of the third component, and the percentage of this third component increases in proportion to the perpendicular distance from this line. This explanation, with a little study of the diagrams will give a clear understanding of the principle involved.

This enables us to plot the proportions of the three fundamental variables on one plane, and therefore to plot any independent function of all these upon ordinates vertical to that plane. The surface passing through the tops of these ordinates furnishes a graphic representation of the variation of the independent variable with changes in the composition of the material under consideration.

This diagram in three dimensions was first used, as far as my information goes, by Prof. R. H. Thurston in the middle seventies to portray the results of an extensive investigation of the properties of the copper, zinc and tin alloys.

This form of model has been used more or less for slag diagrams and slag calculations for a number of years. Various references to it may be found in technical literature, notably in the Transactions of the American Institute of Mining Engineers.

A study of the photographs of Rankin's melting point model shows, first of all, what may perhaps properly be called a general law of nature, that the admixture with a given substance of a small amount of another substance always results in lowering the melting point, since a study of the different views of the model shows that in every case it slopes from the angles of the tri-

angle down, and from the sides, in practically every case, it slopes downward toward the center, thus forming a sort of rough crater with high walls along the sides and much higher peaks at the apices of the triangle. The different ridges and valleys in the diagram are caused by the occurrence of different definite chemical compounds. These are indicated by Fig. 7.

This investigation is one of the most elaborate ever made, and is distinguished from most others, whose results were useless, by the fact that great pains were taken to secure not softening points, but complete liquefaction or melting in every case.

This diagram while interesting from the furnace-man's point of view is difficult to use because the range of alumina commonly and preferably used in furnace practice is only from 5 to 15 per cent, which confines us to quite a narrow belt parallel to the $\text{CaO}-\text{SiO}_2$ side, and within this belt we are further limited to the ratios of lime to silica, which we are permitted to employ especially in coke furnaces.

In order to make the result of this vast scientific work applicable to blast-furnace purposes at least in some degree, I obtained through the great kindness of Mr. Rankin three curves representing sections of the model along the planes of 5, 10 and 15 per cent alumina. These curves have all been plotted on one diagram, Fig. 8, so as to make them comparative. The silica is taken as the independent variable, the alumina is constant on any one curve, and the lime may be obtained by subtracting the sum of the silica and alumina at any point from 100. The curves terminate at different points because obviously in the one representing 15 per cent alumina the silica must be limited to 85 per cent, while in the one representing 5 per cent alumina the silica can go to 95 per cent. Hence the right-hand limits of the diagram are not coterminous.

It will be seen that the diagram contains two sets of lines; the lower one is made up of short sections of vertical and horizontal straight lines, which show that the softening temperatures of the different compounds remain constant over quite wide ranges and then change by sudden jumps, while the changes in the temperature of complete fusion take place along continuous curves, although these latter contain three prominent cusps.

I have added to this diagram a reproduction of the curve shown in Fig. 1, which gives, as already described, my idea of the free-running temperatures of different

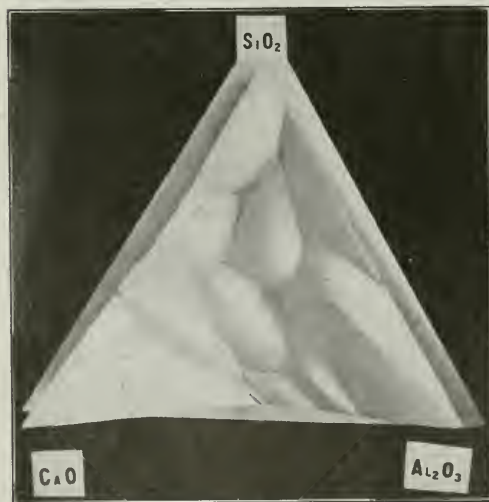


FIG. 6—PHOTOGRAPH OF SOLID MODEL TAKEN FROM ABOVE, SHOWING RELATION OF VARIOUS FIELDS

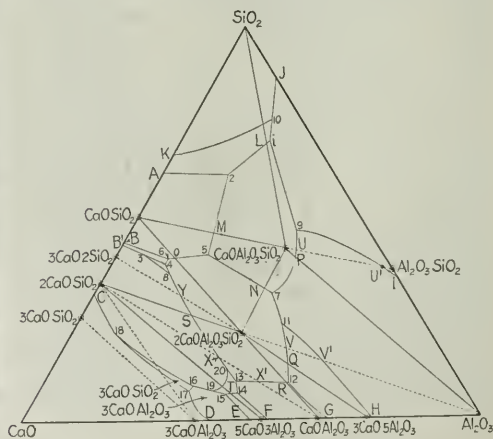
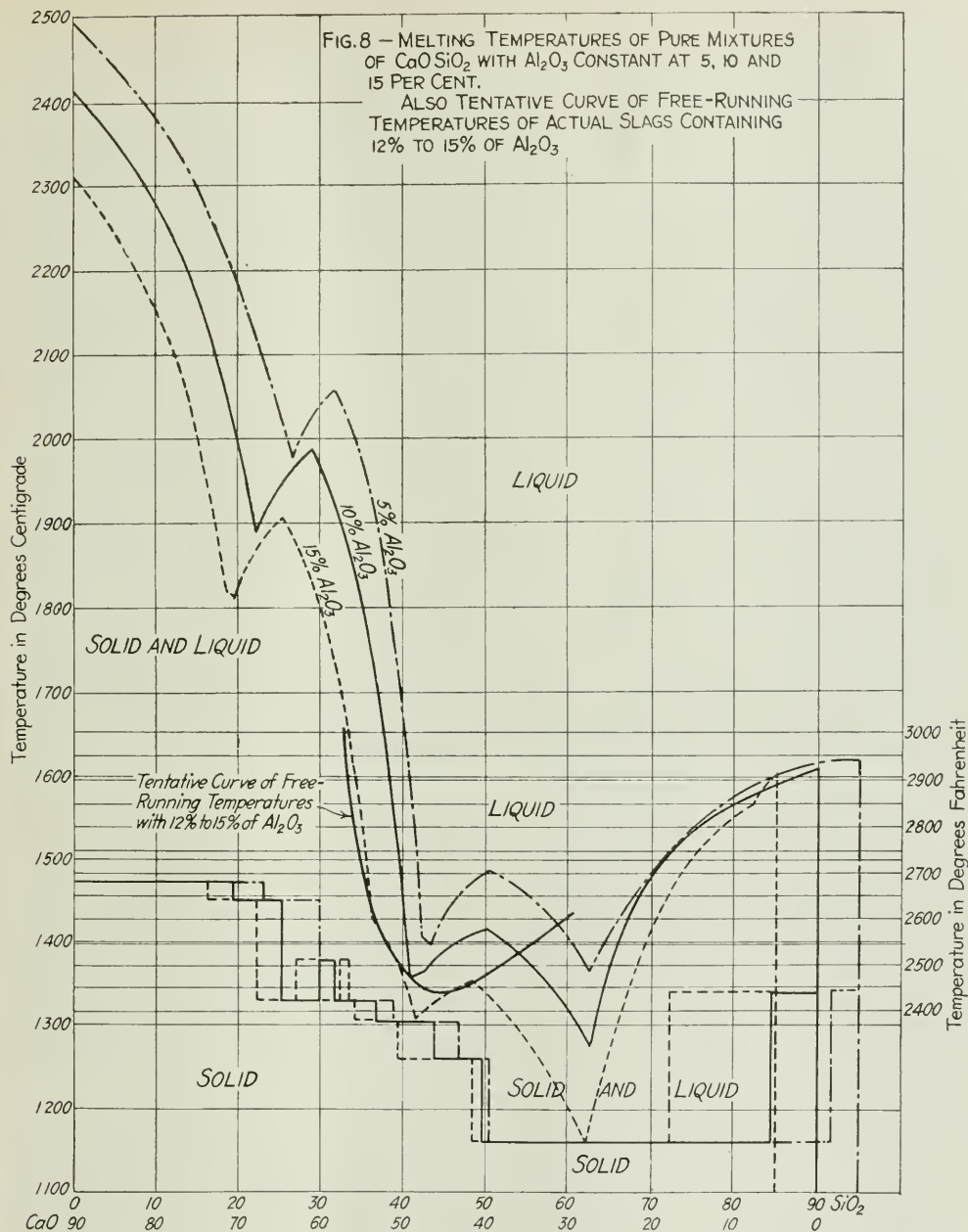


FIG. 7—DIAGRAM OF THE TERNARY SYSTEM, SHOWING THE VARIOUS BINARY SYSTEMS WITHIN TERNARY SYSTEM



slags containing about 15 per cent alumina with different percentages of silica, this curve being drawn as a result of observation and experience, with some pyrometer readings, covering a great many years, but on purely commercial slags always containing other ingredients besides the three represented in the diagram; notable among these are magnesia, calcium sulphide, manganese and iron.

Considering that my curve was laid down simply in

accordance with my experience, and entirely without reference to the correct scientifically derived curve of Mr. Rankin, its agreement with the curve for 15 per cent Al_2O_3 is in my judgment quite remarkable. The fact that it lies in part below the Rankin curve, although it represents free-running temperatures while the Rankin curves give melting temperatures, may be explained either by my being in error or, as I prefer to believe, by the presence of the other ingredients men-

tioned above, magnesia, calcium sulphide, etc., which lower the melting point.

Assuming the reasonable correctness of my curve for free-running temperatures, the tremendous variation in the range between these and melting temperatures is well shown.

It will be noted that the low point corresponding on all the curves to about 62 per cent silica is not reflected in my rough curve. I do not think that I ever ran a furnace on a slag containing more than 56 or 57 per cent silica in charcoal practice, but I have run on one containing that amount. I have heard of others who have run furnaces on even leaner slags, containing up to 63 per cent silica, but I have never heard that they noticed particular fusibility in that region. On the contrary, my own experience and that of others with whom I have talked concerning this little-known subject has been that these slags tended to make a hotter iron than one lower in silica. This is, in my judgment, for the reason that the increase in viscosity due to the higher silica more than compensates for the lower melting point.

I have noticed, however, in charcoal practice that slags of 49 to 51 per cent silica, with about 12 per cent alumina, were distinctly less desirable than slags of somewhat lower silica, which may very well correspond to the high point occurring on all three melting-point curves at or very close to 49 per cent silica. As a result of this fact, I usually preferred to burden the furnace to produce a slag of 46 to 48 per cent silica.

As a result of general observation I should say that the slags from 50 per cent silica up were fusible at a lower temperature than those below that point, but as this fusibility was not of a kind which could be translated into free-running temperature it was not a matter of much moment; in fact, the free-running temperature of the slag in charcoal practice, especially with wet, rich ore, is immaterial, since we have seen that the limitation to fuel economy comes not from a deficiency of hearth heat but from a deficiency of shaft heat. This fact was reflected by the circumstance that we could change the lime-silica ratio of the slag over a very wide range without particularly affecting the fuel economy of the furnace. But the free-running temperature of the slag was of importance because it was quite generally believed that better iron could be made with more fusible slags. The belief, though rather vague and shadowy, was entirely justified by knowledge which we subsequently obtained as to the conditions controlling the quality of charcoal iron, all of which will be explained later.

The range between the scientifically determined melting-point curves and my approximate curve based on experience, which begins to increase at 50 per cent silica, corresponds precisely to the varying range between melting points and free-running points shown by Professor Fulton's curves. It will be noted that leaving out the two downward cusps due to the formation of definite compounds with a low melting point at 41 per cent and 62 per cent silica, the general course of my rough curve follows in a general way the scientifically determined melting point curves; that is to say, the left-hand limb of the curve is very steep, the bottom section approximately horizontal, it then rises again on the right, but much more slowly and to a much smaller height, within any practical limits than the left-hand limb.

In similar wise it will be noted that each increase of alumina, from 5 to 10 and from 10 to 15 per cent, corresponds to a distinct lowering of the fusion point throughout the entire practical range of furnace slags, but this again does not correspond to the facts of prac-

tice, and I think for the same reason the increase in viscosity contributed by the alumina raises the free-running temperature of the slag above its melting temperature by an increased range equal to or greater than the reduction in melting temperature due to the presence of the alumina. This is partly contradicted by one experience of which I have heard. In that case the furnaceman considered that his alumina was too low for good work, and when it fell to about 10 per cent it was deliberately raised by the addition of a more aluminous mixture. This, however, was on an old and badly worn furnace, and on a new furnace with good lines the same tendency did not manifest itself. The furnaceman concerned, who gave me this information, did not seem to feel very positive that he had either proved or disproved anything very positively in regard to this. On the other hand, I have had some experience which leads me to believe that low alumina is really beneficial, even though that fact may contradict the results shown by Mr. Rankin's diagram, for the reason that he determined melting points, whereas the best furnace is concerned only with free-running temperatures.

Mr. Gilbert Rigg of the New Jersey Zinc Company has done an immense amount of research work on slags, and has very generously discussed some of his results and conclusions with me.

His work has tended strongly to confirm my conclusions as to the marked difference in range between melting and free-running temperatures with different slags, and the decided effect of this difference in altering the physical action of the slag.

Mr. Rigg has suggested that when the slag is relatively acid, alumina acts as a base and partly masks the effect of the acidity, but when the slag is relatively basic the alumina tends to combine with magnesia and forms a magnesium silicate known as spinel, which is exceedingly infusible and by its presence very markedly stiffens up the slag.

Moreover, Mr. Rigg states that magnesia and alumina when brought out into intimate contact far below the fusion temperature of either or of the resulting compound form a spinel. Such an action can only have the most serious result in the slag finally formed, and is probably responsible for the bad repute as a flux in which magnesia was held by some furnacemen, especially those of an earlier generation. There was a very general opinion at one time that the formation of spinel led to the building up of the hearth and all the bad consequences of that action. It is quite likely that this did occur in some cases, but I have no definite knowledge of the circumstances, and it does not seem to constitute a serious danger in modern practice. The subject of spinel, like the whole subject of slag, is one concerning which but little is known, or if known the knowledge is not generally available.

GAS IN SLAG

All slag seems to contain a large quantity of gas, not in the form of bubbles, for these are often entirely absent, but presumably dissolved or, as we say to conceal our ignorance of the real conditions, "occluded." This gas may be seen passing off from the slag in large volumes as it runs from the furnace, but is most conspicuous when a ladle of molten slag is quickly dumped; a great cloud of gas is evolved from the running surface of the slag and ceases as soon as the slag ceases to flow, usually in a few seconds. This occurs when the slag is dumped on the dry clean surface of the slag last dumped, and so cannot be caused by the presence of any foreign matter.

It is worthy of note that the gas evolved partakes of the nature of the top gas being produced at the time.

If the furnace is working hot and well, the top gas is white and heavy, so also is the gas evolved from the slag; when the furnace is working "raw" or cold, the top gas is thin and clear, and the gas from the slag is the same.

No satisfactory reason for these changes in the top gas has ever been given so far as known to me, but the relation of cause and effect between the maintenance of the critical temperature of the slag and the proper work of the furnace, on one hand, and between the proper working of the furnace and the nature of the gas, on the other, is so close that one is led to suspect that the fume which gives the gas its thick white appearance is a product of a slag at its proper temperature, and that the gas evolved from the slag is simply a portion of the hearth gas dissolved in the slag. That this gas is combustible is clearly shown by its often burning when a small jet of it comes out through a crack in the pot, though the gas evolved at the time of dumping does not burn.

No considerable investigation of the nature and cause of this gas has ever been made so far as I know, but Mr. Rigg has suggested a very interesting possible result of its presence, which is that the presence of this gas may have a decided effect on the fluidity of the slag. Certainly it is true in a general way that the most fluid slag evolves the most gas.

Mr. Rigg has reinforced this suggestion by citing the case of certain finely divided solids which, when heated, act exactly like liquids as long as they contain any "occluded" gas, but become simply hot granular solids when this gas is all driven off.

As an illustration and confirmation of the broad principles of the nature of slags above set forth there may be cited the following case which came within my experience:

About 1894, when the basic open-hearth furnace began its period of rapid development in this country, a sudden demand sprang up for what has since come to be universally known as basic iron; that is, iron suitable for this process. On account of the severity of the chemical specifications a small premium was offered over the price of mill iron, whose place it took, and the times being exceedingly hard, most furnaces selling iron below the cost of production, the incentive to earn the premium and make this iron was very great.

It is, I believe, generally admitted that the Longdale Furnaces were the first to make this iron in such a way that a very large percentage of the total output came within the chemical specifications of silicon under 1 per cent, sulphur under 0.05 per cent. Other furnaces which made it in those early times ran the best they could under the conditions tending to make the desired product, picked out the suitable irons, and either sold the other at a reduction in price or remelted it.

At Longdale it was at first attempted to make this iron with the use of straight calcite or limestone as a flux, but the destruction of the furnace walls by the extremely basic and infusible slags so produced was very rapid and made the operation difficult and unsatisfactory. Steps were then taken to secure a supply of dolomite containing almost the theoretical percentage of lime and magnesia, and this was substituted for half the limestone in the charge. The result was almost instantaneous. The trouble with the eating away of the furnace walls ceased, and it became possible to run the furnaces regularly and continuously on iron of the specifications given, and it is probable that no furnaces ever exceeded the records of those furnaces in the percentage of good basic iron produced for many years thereafter. It is a matter worthy of remark that one furnace ran for a whole six months without making a

single "off-cast." The reason for the success of these furnaces in making this iron was for many years a matter of speculation among iron and steel people. A part of it was undoubtedly due to the fact that not having high-blast heat available, nothing beyond 850 deg. Fahr., they ran on the high-burden low-temperature basis, and having iron pipe stoves, at an extremely regular blast temperature.

A further factor in addition to the above, all of which has been the subject of previous comment, is the fact (so far as I know never noted in this connection before) that these furnaces ran on an ore very low in alumina and quite high in silicon, so that the alumina in the slag was only about 7 per cent. Owing to the low viscosity of the slag, this tends to produce an iron considerably lower in temperature than the slag, the retardant action of the latter being reduced to a minimum. This fact I confirmed by pyrometric observations made many hundreds of times.

These furnaces, therefore, had for the making of this iron these advantages: the correct principle of manufacture, high burden and low lime, the correct or approximately correct proportion of lime or magnesia in the slag to give the lowest fusion point, very low alumina content to produce a short non-viscous slag, and so avoided superheating the iron.

THE LOSS OF IRON IN THE SLAG

The slag losses of iron are of two kinds. First, iron chemically contained by the slag as a low oxide; second, fine shots of metallic iron mechanically suspended in the slag, and so small that their difference in specific gravity is not sufficient to make them settle out in the time available for that operation. This loss is considerably greater than is usually appreciated. It is probably safe to say that no furnaceman has ever taken up the subject either to investigate the matter or to recover the iron who has not been surprised at its amount.

A few years ago when operating a charcoal furnace from which the slag was crushed and used as road material, I found that between one and two-tenths of 1 per cent of the weight of the iron were recovered in pieces picked out from the streets. A magnetic separator was installed in the expectation of being able to recover this amount by passing the crushed slag over it before shipment. To my great surprise we recovered three times the amount expected. This being a charcoal furnace the volume of slag was exceedingly small, about 400 or 500 lb. per ton of iron, or about half the slag volume in coke practice. Assuming that the coke slag contained as large a percentage of its own weight as the charcoal we should reasonably expect to recover almost 1 per cent of the total iron made by a coke furnace if we could treat this slag the same way. (Since the above was written I find that this percentage is actually being recovered at some coke furnaces.)

At plants where special efforts have been made to settle the slag before disposing of it very respectable tonnages of iron per month are recovered almost without expense. Mr. Reese has probably carried this work further than anyone else, and has recovered iron in this way amounting to hundreds of dollars a month per furnace. Where the slag is handled in hot pots a visit to the slag dump will almost always reveal a vast number of stringers of iron which had evidently settled to the bottom of the ladle during its journey to the dump, and run out underneath the cinder when the ladle was emptied. This is a matter which will undoubtedly receive increasing attention as time goes on.

As regards the iron chemically contained in the cinder the conditions are very different; this is commercially quite impossible of recovery. The amount varies

with the kind of iron produced and the furnace practice—it is in a general way proportional to the color of the slag.

A white slag probably contains one-tenth of 1 per cent of iron or under, while one which contains 1 per cent of iron is dark brown or black. The black slags made when a furnace is in trouble contain very much higher percentages than this. When a furnace is simply cold and making high sulphur iron, but still operating regularly, the percentage is likely to go up to 5 or 7, but when the furnace is in serious trouble, and the cinder too cold to be tapped in the regular way, it runs much higher than this in iron.

As a general thing conditions around the plant at such times are not conducive to scientific investigations of the slag, and not many have been made as far as my knowledge goes. But once or twice when a charcoal furnace under my management was in one of its periodical messes it produced a rather remarkable slag, and analysis of this showed about 25 per cent of iron, and as I recollect it about equal amounts of lime and silica. This slag was almost as fluid as water in spite of an exceedingly low temperature. No determination of the latter was made, but basing the estimate on its appearance as compared with that of many slags whose temperature was determined, I should think that it did not exceed 1800 deg. Fahr. This slag was very interesting from another point of view. In spite of its fluidity it was evidently immediately at the temperature of solidification, because while the stream of slag flowed rapidly on account of its fluidity it was instantly covered with a frozen crust as it came out of the furnace, the whole surface of the runner being covered solidly over with this dead-black crust, and a good-sized hand-ladle of the material, no matter how quickly it was dipped, was covered solidly with this black crust the instant it was dipped, though beneath it was full of this thin fluid slag at a red heat.

This, of course, does not bear on the question of the loss of iron in the slag in normal practice, since such conditions are about as far from normal as they can go without having the furnace absolutely frozen up. It is of interest, however, as showing that as the temperature drops the percentage of iron passing into the slag increases. In fact, all furnacemen who have brought a furnace through a serious "sickness" know that there are certain phases of furnace conditions in which the iron and slag do not separate, or only after a considerable interval of time, coming out of the furnace as a more or less homogeneous solution of one in the other.

In all matters concerning slags, and especially in trying to correlate with the results of practice scientific data based on the use of chemically pure ingredients, we must remember two vital facts: First, the oft reiterated difference between melting temperature and free-running temperature. Second, the important, and at times overwhelming, influence exerted by small quantities of foreign substances upon admixtures of chemically pure materials. All such substances mentioned earlier—magnesia, calcium sulphide, manganese and iron oxide, as well as the alkalis arising from the ash of the coke or occurring in the ore—have a marked tendency to produce silicates of lower melting temperature than those of lime and alumina, and we do not know what effect even small percentages of these materials may produce upon the melting point and free-running temperature of the actual furnace slags which always contain more or less of them.

At the present time it does not seem likely that we shall know anything about this until a great quantity of water has run under the bridges.

New York City.

Wood Flour

BY FREDERICK W. KRESSMANN

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Wood flour is ground or milled wood that has been screened so as to remove coarse particles and also to give particles having some uniformity in size. Wood flour is usually sold as 40, 60 or 80 mesh,* although one large foreign purchaser has the following specification for dynamite flour:

20 per cent must pass through an 80-mesh screen
50 per cent must pass through a 60-mesh screen
100 per cent must pass through a 50-mesh screen

The different properties of a good wood flour are:

- 1st—It must be white
- 2nd—It must be light and fluffy
- 3rd—It must be absorptive

All industries in which wood flour is used (and these will be considered in greater detail later) require a white or very light cream colored flour, although absorptive qualities are demanded in a large degree only in dynamite flours. Color and weight considerations, therefore, limit the species of wood which may be used to the white, light non-resinous conifers and to the white broad-leaved woods like aspen and poplar. Spruce, white pine and poplar are the species most often used. The wood must be barked before grinding and round wood, slabs (barked) and sawdust free from bark may be used.

The grinding of the wood is performed in two distinct types of apparatus—either stone mills or steel burr roller mills. In Europe, particularly Scandinavia, where a great deal of wood flour is made, the stone mills seem to be used exclusively and most of the early plants in this country use this type of mill. The stones are from 40 to 60 in. in diameter and only the lower stone is driven, the upper one being stationary. The mills are driven with water power turbines, since flour produced with other sources of power cannot compete with Norwegian flour ground by water power.

The wood after barking is first reduced to chips by means of the usual type of chipper or hog. These chips along with a certain proportion of the screenings are fed to the mills which are completely inclosed (with the exception of an opening at the top) with an iron or steel cover. Sufficient steam or water is added to prevent firing and also to keep down the dust. The fine stuff from the mill is then drawn or blown through iron pipes or sheet metal ducts to the screening apparatus, which may be of several types, and which may be either bronze wire or silk bolting cloth, for both are used. After screening the flour is packed either in compressed bales (the imported material comes in this way) or else is sacked with automatic sacking and weighing machinery.

Mills of the above type require from 45 to 50 hp. per twenty-four hours per ton (from 1200 to as high as 1500 hp.-hr. per ton) of flour produced, the power requirement being about the same as in the production of mechanical ground wood pulp.

Another type of mill was developed on the Pacific Coast about twenty-five years ago and was designed especially to handle sawdust as a raw material. This grinder consists of a number of pairs of corrugated chilled steel rolls which turn toward each other. One of the rolls rotates three times as fast as the other, thereby actually cutting the sawdust which comes between them. The slower roll has its corrugations arranged so that they form pockets to hold the dust while the faster roll does the cutting. There are three stands or rolls, the corrugations being progressively finer on each stand.

*Screens of bronze wire having 40, 60 or 80 meshes per linear inch.

The sawdust is screened before reaching the first rolls so as to remove slivers, small blocks, etc. It is then passed over a strong electric magnet to pick out any particles of iron or steel present and is also screened through bolting cloth between each pair of rolls to remove material of suitable fineness. The production of wood flour from sawdust in this type of mill requires only from 20 to 25 per cent of the power required with the stone mills.

Before the war Norwegian wood flour was delivered at our Atlantic ports for from \$12.50 to \$15 per ton and domestic material sold in competition therewith. The domestic production is largely controlled by one concern, although mills are scattered all over the country from Maine to California wherever the combination of proper wood and water power is available.

Uses

The principal uses for wood flour are in the manufacture of dynamite, linoleum, artificial plastics and flooring, and as an inert absorbent in many industries.

DYNAMITE

Dynamite consists essentially of nitroglycerine absorbed in some porous material. For this purpose wood flour, wheat flour mill refuse, and infusorial earth (kieselguhr) are the principal materials used and wood flour is the one commonly used to-day. In addition, a certain amount of oxidizing material, either sodium or potassium nitrate with traces of calcium carbonate, magnesium carbonate, or zinc oxide are used. The latter materials are added to neutralize any free acid that may be formed by the decomposition of the nitroglycerine in long storage.

The composition of typical dynamites is as follows:*

Moisture ..	1.4
Nitroglycerine ..	60.6
Sodium or potassium nitrate ..	44
Wood flour ..	15
Calcium carbonate ..	1
	1.2

A dynamite flour must be both white and highly absorptive. Since dynamite darkens with age a light-colored stick is indicative of fresh stock and trade demands, therefore, require the use of a white flour. For this reason it would be practically impossible to introduce the use of a wood flour produced from any colored woods. A good flour should be capable of making a 60 or 70 per cent dynamite (60 or 70 per cent of the total weight being nitroglycerine) without permitting leakage or exudation of nitroglycerine.** It is possible to improve the absorptive qualities and power of a flour by mixing it with water, boiling it actively for a short time and then drying, although this process, of course, increases the cost of production appreciably. For dynamite purposes, therefore, wood flour must be as white as possible, it must be absorptive and must be of the proper weight not only because the size of stick and number of sticks per box is standard, but also because too much flour cannot be used because it would disturb the carbon and oxygen balance in the explosive.

In 1900 over 85,846,000 lb. of dynamite were produced in the United States, containing over 9,934,000 lb. of wood flour. In 1909 the production of dynamite increased to about 195,156,000 lb., although the amount of wood flour used in this dynamite was not stated. The proportion of wood flour used in dynamite in 1909 was probably greater than in 1900 because of a tendency to produce dynamites of greater strength and the gradual replacement of other absorbents with wood flour. The 1909 consumption of wood flour for dynamite was probably around 20,000,000 lb. Since 1909

the production of dynamite has no doubt continued to expand and develop as before.

LINOLEUM

In the manufacture of linoleum, wood flour is used exclusively in the production of goods belonging to the inlaid class, either "granulated inlaid" or "straight-line." Cork linoleum is always dark, either the natural brown, or dark red or green. Patterns are printed on cork linoleum, but the pattern soon wears off, leaving the dark base. For the production of inlaid goods in which the pattern goes clear though the piece to the burlap backing a white base is naturally necessary, not only to furnish a white background where desired but also to permit of dyeing to any color. For this reason a flour as white as possible is desirable.

Linoleum consists of wood flour or cork flour mixed with a cementing material which is spread out on burlap and rolled or pressed hydraulically thereon. The cement consists of oxidized linseed oil melted with rosin and Kauri gum. The cement is the expensive constituent, it being worth from \$125 to \$175 per ton, depending on the price of linseed oil. Naturally the lightest flour will produce the largest volume of goods, since the raw materials of linoleum are purchased on a weight basis and sold on a volume basis. The weight per cubic foot is, therefore, along with the color, of prime consideration to the linoleum manufacturer.

The following table shows the comparative weights per cubic foot of cork and wood flours of different sizes:

23-mesh cork ..	6.25 lb. per cubic foot
50-mesh cork ..	7.50 lb. per cubic foot
80-mesh wood, imported ..	13.0 lb. per cubic foot
40-mesh wood, domestic ..	9.0 lb. per cubic foot

Another manufacturer reports as follows:

26-mesh cork ..	4 to 4.5 lb. per cubic foot
60 to 80-mesh wood, imported ..	4.8 lb. per cubic foot
60 to 80-mesh wood, domestic ..	6.8 lb. per cubic foot

The difference in the above figures is due chiefly to the method of measuring and the amount of tamping in the measure, but in either case the wood flour weighs about 50 per cent to 100 per cent more than the cork. Cork waste before the war was worth about \$35 per ton and it costs about \$5 per ton to grind it with power at 1½ cents per kilowatt. Practically all cork flour used in this country is ground here either from domestic waste or waste from Spanish cork mills. Cork flour is, therefore, worth about three times as much as wood flour, but since they both require equal amounts by weight of cement and since the latter is the expensive item and also because the volume of goods produced from cork is so much greater than that from wood, the cork linoleum is cheaper for goods of equal thickness than wood flour linoleum. Cork linoleum is also cheaper to manufacture than wood linoleum because it is simply rolled between calendar rolls, whereas the production of inlaid linoleum requires a considerable amount of handwork in the production of granulated inlaid and also a tremendous expense for dies in the production of "straight line." The seasoning time for cork is also less than wood flour linoleum of equal thickness. Cork linoleum is slightly more elastic than wood flour linoleum, although wearing qualities are about the same.

Here also the importance of a white flour with a low weight per cubic foot (fluffiness) is noted.

In 1909 about 4,460,000 sq. yd. of different kinds and thicknesses of inlaid linoleum were produced in this country. No statistics are available in which this production is classified into different thicknesses and grades. In general, however, the grades most commonly used will weigh from 8 to 12 lb. per square yard (exclusive of the weight of the paint backing) and will contain from 40 to 50 per cent of wood flour.

*Bureau of Mines Bulletin No. 51, "The Analysis of Black Powder Dynamite," by W. O. Snelling and C. G. Storm.

**For pressure and centrifugal tests see page 9, Bulletin 51, Bureau of Mines.

MINOR USES

For composition flooring, plastics, oatmeal paper, etc., the principal requirement is light color, although in some cases certain species are necessary as in the production of artificial bates for tanneries. The latter consists of a mixture of wood flour, ammonium chloride and certain animal extracts which are absorbed by the wood flour. Here again the trade demands a light colored product and it has been found that flour from broad-leaved woods like poplar will cause a discoloration on storage so that only flour from spruce or white pine may be used.

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Antimony Production in Hunan Province, South China

It is well known that China has for many years held the position of the world's largest producer of antimony. In view of the shortage of antimony in this country and the present attempts to smelt antimony ore here, the following excerpt from an article by A. S. Wheeler in the *Bulletin* of the Institution of Mining and Metallurgy (London), Feb. 17, 1916, should prove interesting.

The province of Hunan, in South China, is the chief source of the Chinese supply. The chief mine is the Hsi-K'eng-shan field, and is generally referred to as the Sinhua mines. The ore is stibnite Sb_2S_3 oxidized in places to cervantite. It is of remarkable purity, carrying a fraction of a per cent of arsenic and traces of lead and copper. The entire field is in the hands of Chinese.

The ore is rough-sorted underground and carried to surface in basket loads of 60 cattie (79 lb.) weight or more. It is then cobbled or close-cored. The picked ore averages about 60 per cent Sb; the balance, together with the fines and mine sweepings, is reduced by hand to a size corresponding to $\frac{3}{4}$ -in. or $\frac{1}{8}$ -in. mesh, and is subjected to repeated concentrations by hand-jigging in shallow circular baskets immersed in water. The men who do this work become extremely expert and rapid at it; with a few half turns and a back shake or two they bring the waste to the top, skim it off, and repeat the process until the material has been concentrated to about 45 per cent metal.

Owing to the boom in antimony the waste heaps and dumps are being minutely gone over and their contents graded up by cobbing and concentration, this work being usually left to the "small workers," or poorer people, who sell the product to the mine owner at 2000 to 3000 cash per picul.

There are seven local smelting works, two of which are privately owned, the balance being customs works.

These are all turning out crude only, with the exception of the Mei-hsiang Company, which also started to produce regulus by smelting the oxide ore in reverberatory furnaces. Their total output had only amounted to about 100 tons, when the Hua Chang Smelting Co. of Changsha, who held the monopoly in China for the production of regulus, and also have powerful friends at Court, successfully protested, however, against what they regarded as an infringement of their rights by the Mei-hsiang Co., with the result that the latter concern was recently absorbed by them. This monopoly, it should be mentioned, has since been considerably curtailed, and is now in force only within 100 li of Changsha city.

The smelters make an all-round returning charge of 15 strings (16s. 3d.) per ton of crude produced, and will not accept ore below 40 per cent grade; this,

however, is estimated solely by its appearance. The ash is the smelters' perquisite, and the local coal costs 5 strings (5s. 5d.) per ton delivered. A description of this process, which is the same throughout the province, is given later under the heading of smelting.

The output of crude from this field is placed at rather over 1000 tons per month, but in addition to this a few hundred tons of high grade ore are shipped to Changsha for treatment or export.

Next in importance, but coming a poor second, are the Panshi mines, the output of which (about 400 tons of 30 per cent Sb grade) goes to the Hua Chang Co.'s works at Changsha where it supplies the Herrenschmidt furnace mentioned later, employed in the production of regulus.

There are numerous other smaller producers and the stimulus given to antimony mining by the rise in price has resulted in the profitable working of many small mines, which under normal conditions are unrenumerative. A few thousand tons of high-grade ore, and a small quantity of "ash" or liquation residues, are exported annually, but the bulk of the production is marketed in the form of "crude" and "regulus." These two terms are misnomers sanctified by long usage; the term "antimony crude" being applied to the product obtained from liquation of the sulphide, stibnite, and "regulus" meaning the metal, sometimes inaccurately styled, "refined antimony."

The type of furnace employed by the Chinese for the production of crude is the same throughout the province. It consists as shown in Fig. 1, of a narrow furnace built of ordinary brick and containing two pairs of pots or crucibles. The upper one of each set, into which the ore is charged, is fitted into the lower as shown, and the molten sulphide trickles through a $\frac{1}{2}$ in. hole in the bottom edge of the upper pot into the lower one which is bedded in the sand or ashes in order to avoid the full temperature of the furnace. A flue along the top of the furnace connects with the main flue or chimney about which the furnaces are invariably built in pairs, though it will be observed that each pair of crucibles is fired independently, being separated from its neighbor by a partition wall.

A moderate draught ensures the red heat necessary to effect fusion, and when sufficient of the liquated sulphide has accumulated in the lower vessel it is ladled out into moulds and solidifies into ingots of about 16 lb. weight each. These, when fractured, show a well-marked and characteristic acicular crystallization at right angles to the cooling surface.

The ingots are packed for shipment in wooden boxes containing 224 lb. net, and of 240 lb. gross weight.

The furnace is simple in design and cheap to build, and does not require much skill or experience to operate; one man usually attends four furnaces per 8-hour shift, for which he is paid 8 to 10 strings (say, 10s.) per month, in addition to his food.

The disadvantages of intermittent working and inefficiency do not appear to outweigh the good points in Chinese eyes, and no effort is made to check the continuous escape of fume which is so evident.

The pots used are usually of local manufacture, and have a life of 10 to 15 days; they contain a charge of 45 to 60 cattie of ore, which takes from 2 to 4 hours to run down; it is not found that fines and dust in the charge cause any trouble.

The local method of estimating the content of an ore is by the number of units (tenths) of crude produced per picul, disregarding volatilization and residue losses. Thus a parcel of ore is tested by putting

a sample of one picul weight through the furnace just described and weighing the resultant crude. No allowance is made for residue of volatilization losses, the ash and flue dust being the perquisite of the smelter; hence it can be readily understood that there is ample scope for dishonest practice.

It is found that a high-grade ore, assaying 60 per cent Sb, yields about 70 per cent crude by this process, corresponding to an actual extraction of 83 per cent; whilst an ore containing 45 per cent Sb yields only 40 per cent crude, equivalent to a 64 per cent extraction.

The difference is mainly accounted for in the ash or residue, which rarely contains less than 12½ per cent, and may exceed 30 per cent Sb; this is used in the manufacture of regulus. The balance is made up by volatilization, and may be reckoned at 3 per cent to 5 per cent of the original Sb_2S_3 content; this is partly recovered in the form of flue dust.

Crude varies from 68 per cent to 78 per cent Sb

cating with an exhaust fan, which blows into a scrubber or coke-tower sprayed with water.

The essential feature of the process lies in the regulation of the admission of air, whereby the ore is subjected to a volatilizing roast, producing Sb_2O_3 , which is immediately drawn off and condenses in the form of a pink-colored powder.

It is removed from the chambers through handholes, and is then smelted in reverberatory furnaces with coal, charcoal or coke, and soda ash, the latter serving as a protective covering and reducing any Sb_2S_3 present. There is, however, a considerable loss by volatilization of the Sb_2S_3 , which is partly recovered as flue dust; the total loss may exceed 30 per cent of the original Sb content of the ore or ash.

The oxide ores, which range in metal content from 40 per cent to 80 per cent are smelted direct in reverberatory furnaces. The Mei-hsiang Company at Sin-hua stated they were smelting a 45 per cent oxide ore, using as flux 14 lb. powdered coal and 5 lb. soda

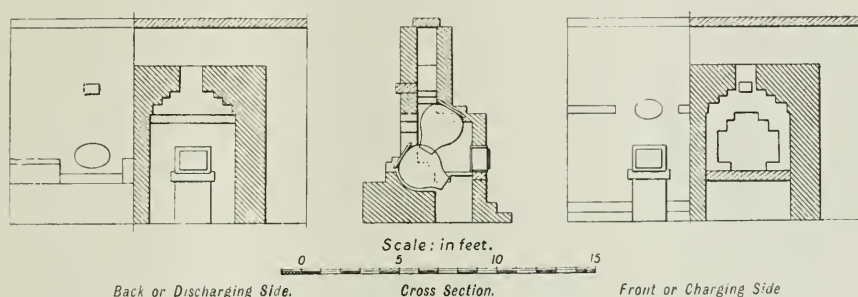


FIG. 1—ANTIMONY CRUDE LIQUATION FURNACE

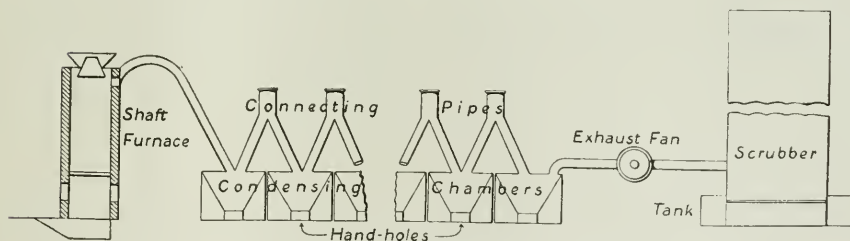


FIG. 2—DIAGRAM OF HERRESHMIDT FURNACE (NOT DRAWN TO SCALE)

and is sold as 70 per cent standard which corresponds to 98 per cent Sb_2S_3 .

Regulus is produced principally from the lower-grade ores, containing about 30 per cent Sb, and from liquation residues, and to a less extent from the oxidized ore, cervantite, which contains 79 per cent Sb when pure.

The Hua Chang Company who, as previously mentioned, hold a monopoly for the production of regulus within a radius of 100 li (36 miles) of Changsha city, also own the patent rights for China of the Herreshmidt furnace. This appliance (See Fig. 2) consists of a shaft furnace into which the ash or ore, previously broken small by hand and mixed with 10 per cent of coal, coke or charcoal is charged. Leading from the furnace is a line of condensing chambers connected with each other by cast iron pipes of ample diameter (12 in. or more) passing from the top of one chamber with an inverted V bend into the top of the next chamber, and finally communi-

ating with an exhaust fan, which blows into a scrubber or coke-tower sprayed with water.

Some regulus furnaces have recently been built in Hankow in which air blast is supplied at the grate and the condensing chambers are water-cooled, but otherwise follow the lines of the Herreshmidt.

Analyses show Hua Chang regulus to contain from 98 per cent upwards of metal, with 0.15 per cent arsenic, and trace of lead, copper and zinc. Generally speaking, the purity of both the crude and the regulus is due to the remarkable freedom of the ores from associated deleterious minerals such as mispickel, galena, copper pyrites, and blende.

The American Society of Mechanical Engineers will hold its spring meeting at New Orleans from Tuesday, April 11, to Friday, April 14, inclusive.

Belgian Chemical Industries

The chemical industries of Belgium before and during the war which were more or less developed are discussed by Professor H. Hubert, of Liege University, in an article in *The Engineer* (London).

MINERAL ACIDS AND PHOSPHATES OF CALCIUM

Twenty-seven companies were engaged in the production of sulphuric acid. For a long time it was made only by the so-called chemical factories, established in the valley of the river Sambre and near Antwerp. But some years ago the manufacturers of zinc were obliged, in order to avoid troubles in the neighborhood and numerous complaints and suits, to abandon the simple roasting of their blende and to transform their sulphurous acid into sulphuric acid or to erect special works for this purpose. Of course, this transformation increased considerably the output of sulphuric acid, which now reaches 320,000 tons per annum. Thirteen works produced nitric acid, the greatest part of which is used in the manufacture of sulphuric acid, nitroglycerine, dynamite, and nitrocellulose for smokeless powder and artificial silk. The material used is the Chili nitrate of soda. A small quantity is used for the production of nitrates of ammonia. The total yearly output is over 11,000 tons. The production of hydrochloric acid by eleven works amounted to about 30,000 tons per year, and was regulated by the Co-operative Company Union Commerciale and partially exported to Germany and Holland. Superphosphate of lime was manufactured by thirty-three works, sixteen of which produced their own sulphuric acid. The total yearly output was about 350,000 tons, thanks to the importation of phosphates from the region of the river Somme in France and of Florida in the United States. Half the production of superphosphate was exported to France, Spain, Holland, and to the Baltic harbors. The steel works, which use the Thomas and Gilchrist process, produce yearly about 225,000 tons of phosphatic basic slag, which is treated in five of these works and in six other shops.

POTASSIC, SODIC, AMMONIC, AND CALCIC SALTS

The principal product in this class is the carbonate of sodium, or soda, which was formerly manufactured by means of the Leblanc process—reaction of carbon on chloride of sodium to produce sulphide of sodium, and decomposition of this latter by carbonate of calcium, which forms carbonate of sodium and sulphide of calcium. In 1838 two Englishmen, Dyar and Hemming, patented a new process, in which chloride of sodium is treated by carbonate of ammonium and gives bicarbonate of sodium. This latter is transformed into carbonate by roasting. They did not succeed industrially, and other Englishmen, like Muspratt in 1840, Gossage and Deacon, and the German Kunheim in Berlin, were not more happy. In 1863 the famous scientist and philosopher, Ernest Solvay, in his turn tried this process and erected in Couillet, near Charleroi, works which were the starting point of the great soda industry. Some time later M. Solvay founded the Dombasle Works, near Nancy, and granted a license to Messrs. Brunner, Mond & Co., Northwich. These two works are still the most important in the world, producing yearly one 150,000 and the other 200,000 tons. Later, M. Solvay established in 1883 the Bernsburg Works in Germany and the Beresnicki Works in Russia; in 1884 the big Syracuse Works in the United States and the Ebensee Works in Austria, etc. The Couillet Works are still in activity, and produce yearly about 25,000 tons. Carbonate of ammonia was first produced only by gas works. The need of large quantities of this matter induced numerous collieries to build recovery coke ovens, some of which

were erected by Messrs. Solvay at their own cost, the collieries agreeing to give them the by-products while reserving their coke.

VARIOUS INORGANIC CHEMICAL PRODUCTS

The Overpelt Works, in Limburg, the principal production of which is zinc and lead, manufactured also sulphate of copper, arsenious acid, oxide of nickel, and of cobalt. The Vieille Montagne Company produced also more than 6000 tons of oxide of zinc, or *blanc de zinc*.

EXPLOSIVES

The continuous development of mines and quarries in Belgium required, of course, the production of a large quantity of explosives, and led to the establishment of an important industry which was not only able to meet the whole national needs, but to supply several countries in Europe and in other parts of the world. Fifty works manufacture the different explosive products, the total output of which may be rated at 4000 tons and estimated at £300,000, in value, the third of which is exported. The smokeless powders, the basis of which is nitrocellulose, are manufactured in the two principal works of Belgium—500 tons. The manufacture of matches, which may be connected with the explosive industry, is concentrated in East Flanders. Nine works manufacture wooden and two wax matches, to a total value of nearly £175,000 per year. Sweden and Germany import yearly matches worth about £14,000, but this importation is decreasing, while the Belgian exports reach more than £100,000, specially to England, her Colonies, and the Mediterranean countries.

THE MANUFACTURE OF ARTIFICIAL PORTLAND CEMENT

This began in Belgium about forty years ago, and developed rapidly on account of the important need for buildings and engineering construction, and of the facility of obtaining the ingredients. This development led to the erection of numerous and large works in the provinces of Liège, Namur, Hainaut, Brabant, and Antwerp, which had an output of about a million tons, largely surpassing the national needs, half of which was exported to England and her colonies, to the United States, and South America. Several metallurgical companies—for example the John Cockerill Company—manufacture a special cement by mixing their blast-furnace slags with lime, hard bricks being also made from slags.

Electric Steel Furnaces In England

In *London Electrical Engineering* of March 2 a review is given of the present position of the electric steel furnace in Sheffield. It is pointed out that the war has been a means of bringing the quality of the electric furnace for steel refining well to the front.

Three types of electric steel furnaces are in use in Sheffield, and "it is satisfactory to learn that all three types give excellent results. The Heroult type of furnace is much in evidence, the company having at their disposal a large amount of actual practical experience. The type of furnace manufactured by Electro-Metals, Ltd., has also found favor, while there is one example of the Rennerfelt furnace in regular operation."

The general practice of steel refining is the same as in this country. Two slags are used; by the first a phosphorus is removed, by the second sulphur. The article concludes: "The trend of events at present seems to indicate a very important future for the electric steel furnace; it is fortunate that in Sheffield this is well catered for by the energetic and up-to-date policy pursued by the Corporation Electricity Department." Thus it seems that the electric steel furnaces are supplied with power from the central station supply system.

The Available Hearth Heat of the Blast Furnace

BY ALEX. L. FEILD

It is in no spirit of criticism that the author approaches the fundamental hypothesis of the series of articles by J. E. Johnson, Jr.,¹ which have recently appeared in this journal. No furnace man can consistently deny that Mr. Johnson's new hearth heat balance answers numerous problems which baffled the old style "heat balance" of Bell and his co-workers. What I would impress upon the reader at the outset is that the present article should be considered in the light of an interpretation, from the viewpoint of the physical chemist, of the important work of Johnson in having solved, more completely than had been before accomplished, some of those perplexing operating problems which confront the works superintendent at every turn.

However much I would emphasize the value of the hearth heat balance, I wish to state that Mr. Johnson seems to have regarded the fundamental laws which form the basis of his theory from the standpoint of the engineer rather than that of the physical chemist.

The "hearth heat" theory undoubtedly agrees well with the results obtained in practice. It should certainly do so, because it is essentially the logical method. However, in spite of the fact that the idea behind the theory which has been presented in the series of articles above mentioned is the correct one, the method of interpreting and of establishing this theory seems unfortunate.

In the opening instalment of the series² it is stated in effect that the blast furnace depends upon a law, similar to the second law of thermodynamics, in addition to the first law, which forms the basis of the heat balance of Sir Lothian Bell. As we shall see later, Mr. Johnson, throughout his series of articles, has made use only of the first law of thermodynamics—i.e., the law of the conservation of energy. In fact, the fundamental principle upon which it is possible to derive Mr. Johnson's data is none other than Hess' law of constant heat summation, which was promulgated even before the doctrine of the conservation of energy was firmly

established. The expression, $\frac{T_1 - T_2}{T_1} \times Q = Q_a$, derived

by Johnson³ (T_1 being the theoretical combustion temperature, T_2 the critical temperature, Q the total heat, and Q_a the hearth heat) and attributed by him to the second law of thermodynamics has no direct connection with the second law, for the very obvious fact that it does not contain a single expression or term which represents the conversion of heat or chemical energy into either mechanical or electrical work. It represents in reality only a heat transfer, although it does bear a superficial resemblance to the expression for the maximum efficiency of a gas engine operating in a Carnot cycle. The conversion of chemical energy into work is expressed by the familiar free energy equation⁴ $A = RT \ln K$, which is based upon the second law of thermodynamics and the law of mass action. It is sometimes called the equation of the "reaction isotherm." However, neither this particular equation nor the general principles of the conversion of heat into work, or vice versa, is pertinent to the present discussion; nor does Mr. Johnson attempt to use the second law of thermodynamics.

The usual method of calculating the theoretical tem-

perature of combustion is essentially that of Johnson in calculating the critical temperature diagram⁵. With a critical temperature equal to the theoretical temperature of combustion the hearth heat is simply equal to zero.

In a nutshell, Mr. Johnson's "hearth heat" or "available hearth heat" at a "critical" temperature of 2750 deg. Fahr. is equal to the heat of the reaction, carbon + oxygen = carbon monoxide, at a temperature of 2750 deg. Fahr. minus the amount of heat necessary to raise the blast up to 2750 deg. Fahr. For the sake of brevity we will consider in the present article only the case of the dry blast. The simplified method of attacking the problem which will be presented should make it readily possible for the reader to extend it to the moist blast.

If we let Q_H equal the hearth heat, Q_T the heat of the reaction at a critical temperature T , and H_B the mean heat capacity of the air of the blast between the temperature T and the temperature of the blast T_B , we have, from the preceding paragraph,

$$Q_H = Q_T - H_B(T - T_B) \quad (1)$$

While the author does not intend to discuss in the present article the exact nature of the "critical temperature" nor what it really corresponds to, i.e., whether it is equal to the temperature of the freely flowing slag, the temperature at the tuyeres, or any other similar temperature—it seems to him desirable to establish according to well-known laws the equation which gives us the hearth heat at any particular critical temperature. It may be remarked here that Mr. Johnson's method of calculation ought to give comparable numerical results were there not a difference in the values used for the specific heat of carbon, which Mr. Johnson takes equal to about one-half the generally accepted value.⁶ He has consistently taken as the mean specific heat of carbon between 0 deg. Fahr. and 2750 deg. Fahr., the value 0.23, whereas, according to the data of Richards⁷ which he accepts and which we shall make use of entirely for the purpose of direct comparison, this value should be 0.43. The values for hearth heat obtained by Mr. Johnson while using the value 0.23 are much too low, the percentage error introduced being largest for high critical temperatures.

THE HEAT OF REACTION AND THE HEARTH HEAT AT ANY TEMPERATURE T .

As is well known, the heat of reaction varies with the temperature. The heat of reaction at any temperature T is defined as the quantity of heat evolved or absorbed when both initial and final products are at the temperature T . In general, thermochemical measurements are made at room temperature because it is convenient.

Consider now the two following processes⁸ to take place. First, allow a chemical reaction (in our case the combustion of carbon to carbon monoxide by oxygen) to occur at a temperature T ; heat the products of combustion to a slightly higher temperature $T + dT$. Secondly, heat the reacting substances from T to $T + dT$ and allow the reaction to occur at a temperature $T + dT$. According to the law of conservation of energy, the total heat evolved in the two processes must be equal. Let Q be the heat of reaction at the temperature T , and $Q + dQ$ the heat of reaction at the temperature $T + dT$. Then $Q - h'dT = Q + dQ - h dT$, where h and h' are the mean heat capacities of the reacting substances and the products respectively. Therefore,

$$\frac{dQ}{dT} = h - h' \quad (2)$$

¹Op. cit., p. 720, Fig. 1; also p. 789, Fig. I.

²Op. cit., p. 720.

³Op. cit., p. 791. Also, J. W. Richards, "Metallurgical Calculations," Vol. I, 1906.

⁴See Walter Nernst, "Chemistry and Thermodynamics," pp. 10-12. Chas. Scribners Sons, 1907.

⁵J. E. Johnson, Jr., "Thermal Principles of the Blast Furnace," Met. Chem. Eng., Vol. 13 (1915), pp. 718, 787, 832, 905 and 954.

⁶Op. cit., p. 718.

⁷Op. cit., p. 833.

⁸Walter Nernst, "Theoretical Chemistry," p. 644. 1914. Macmillan & Co.

Equation (2) shows that the increase in the heat of reaction per degree is equal to the difference between the mean heat capacities of the reacting substances and products of the reactions. This is none other than Hess' law. Therefore, if Q is known for any particular temperature and if the specific heats of the substances involved are known, together with their dependence on the temperature, it is possible to draw a curve showing

the relation between Q and T , while $\frac{dQ}{dT}$ in equation (2)

is the slope of the curve at any temperature T .

Integrating equation (2) we get

$$Q_T = Q_o + (h - h') T$$

or

$$Q_T = Q_o + hT - h'T = Q_o + h_c T + h_o T - h_{co} T \quad (3)$$

where

h_c = mean heat capacity of carbon between T_o and T ,

h_o = mean heat capacity of oxygen between T_o and T ,

h_{co} = mean heat capacity of carbon monoxide between T_o and T ,

and

Q_o = heat of reaction at T_o , where T_o is the arbitrarily chosen reference temperature, such as the freezing point.

Equation (3) gives Q_T , the heat of reaction at any temperature T , due to the combustion of carbon to carbon monoxide at the tuyeres. However, from this heat of combustion we must subtract the heat necessary to raise the blast up to the temperature T in order to get the amount of heat which is available. We will call this remaining heat Q_h , since it will be found to correspond to Johnson's hearth heat. Equation (1) gave us the relation $Q_h = Q_T - H_B(T - T_B)$. Now H_B is made of two parts, h_o and h_n , the mean heat capacities of the oxygen and nitrogen in the air of the blast respectively. Substituting $H_B = h_o + h_n$ in equation (1), we have

$$Q_h = Q_T + h_o T_B + h_n T_B - h_o T - h_n T \quad (4)$$

Substituting in equation (4) the value of Q_T from equation (3) and eliminating, we get

$$Q_h = Q_o + h_c T + H_B T_B - h_{co} T - h_n T \quad (5)$$

Equation (5) corresponds to Johnson's method⁹ of calculating Q_h , the hearth heat, for any critical temperature T . This method, as has been seen above, can be derived directly from equation (1), which is the expression we shall use in calculating Q_h , the hearth heat.

We see, therefore, that the hearth heat at any given critical temperature is equal to the heat of the reaction at that temperature minus the heat necessary to raise the blast up to the temperature T . For any given "critical" temperature T the hearth heat is a linear function of the blast temperature and has the general form $A + H_B T_B$, where A is a constant for any given critical temperature and equal to $Q_T - H_B T$.

When Q_h , the hearth heat, is equal to zero, then T , the critical temperature, is equal to the theoretical temperature of combustion for the given blast temperature. From Johnson's diagram¹⁰, we find by referring to the X-axis intercept (*i.e.*, $Q_h = 0$), that, according to his calculations the theoretical temperature of combustion with cold (70 deg. Fahr.) blast is equal to 3090 deg. Fahr. According to the calculations which follow, this theoretical combustion temperature should be 3400 deg. Fahr.

Table 1 gives the values of Q_T , the heat of reaction at various critical temperatures. Table 2 gives the heat required to raise the blast from 32 deg. Fahr. to T deg. Fahr., where T is the critical temperature. By

means of these two tables it is possible to calculate the hearth heat Q_h for any given conditions by means of equation (1). The term $H_B(T - T_B)$ in this equation is gotten by subtracting from the heat required to raise the blast from 32 deg. Fahr. to T deg. Fahr., the heat required to raise the blast from 32 deg. Fahr. to T_B deg. Fahr., the temperature of the blast. Both of these last quantities are given in Table 2. In the tables, temperatures are given for convenience in both Fahrenheit and Centigrade degrees. All heat values, however, are expressed in B.t.u. per pound of fixed carbon burned in the hearth.

Fig. 1 shows graphically the value of the hearth heat for various critical temperatures and for dry blast at different temperatures. This revised diagram is similar to Johnson's diagram, except that the hearth heats are calculated for 1 lb. of fixed carbon burned instead of for 0.85 lb. For the sake of direct comparison, the hearth heat isotherms for blast temperatures of 70 deg. and 1400 deg. Fahr.—the two extreme cases considered—have been taken from Johnson's diagram, reduced to a common basis of 1 lb. fixed carbon, and plotted as dotted curves (see Fig. 1). The error introduced by using 0.23 as the mean specific heat of carbon between 0 deg. and 2750 deg. Fahr. is readily seen by comparing these dotted curves with the corresponding revised curves.

TABLE 1—HEAT OF REACTION

T		Q _T Heat of Reaction B.T.U. per Lb. Fixed Carbon
Critical Temperature Deg. Fahr.	Deg. C.	
2192	1370	4674
2372	1300	4707
2552	1400	4738
2732	1500	4772
2912	1600	4805
3092	1700	4835
3272	1800	4865
3452	1900	4897

TABLE 2—HEAT FOR RAISING BLAST TEMPERATURE

T		Heat Required to Raise Blast from 32 Deg. Fahr. to T Deg. Fahr. for 1 Lb. Fixed Carbon Burned
Deg. Fahr.	Deg. C.	
32	0	0
212	100	242
392	200	490
572	300	740
752	400	994
932	500	1242
1112	600	1501
1292	700	1764
1472	800	2016
1652	900	2284
1832	1000	2538
2012	1100	2812
2192	1200	3089
2372	1300	3346
2552	1400	3629
2732	1500	3915
2912	1600	4176
3092	1700	4468
3272	1800	4727
3452	1900	5027

One does not need to go far to find a simple explanation of why calculations based on the low hearth heat values of Mr. Johnson correspond as closely as they appear to do with the results of blast furnace practice. It is obviously because the fuel economy realized by a change of blast temperature, from 400 deg. to 1000 deg. Fahr., for instance, depends upon the difference between two hearth heat values. Now, although the error in the actual value of the two hearth heats may be considerable, the error in the difference of any two hearth heats is much smaller.

In regard to the way in which the available hearth heat is utilized, Johnson¹¹ says:

"It may be said without reservation that for every set of furnace conditions there is a certain critical temperature above which only certain necessary operations of the process can be carried out. It is not necessary to know what the operations are, and no attempt is made

⁹Op. cit., p. 720.

¹⁰Op. cit., p. 720, also p. 789.

¹¹Op. cit., p. 719

to enumerate them here, further than to say that they probably comprise the removal of the final traces of oxygen from the ore, the formation and subsequent superheating of the cinder, and the melting, carbonization, and superheating of the iron—"superheating" being used in the sense of heating above the point of fusion."

If the critical temperature is taken, as it is by Mr. Johnson, as the temperature of the freely flowing slag, it is impossible to explain how the heat required for the melting and superheating of the cinder above its melting point can be supplied above the critical temperature, which is higher than the melting temperature. Although we may assume, for instance, that on account of the physical state of the slag-forming materials in the smelting zone the materials must be heated as high as the critical temperature before slag formation is completed, it must be remembered that the slag thus formed at the critical temperature is already sufficiently superheated to flow freely and requires no heat above the critical temperature. It seems reasonable to assume that the formation temperature of the slag is no higher than its freely flowing temperature. If the formation temperature were higher than the critical temperature, the melted slag would be at a higher temperature than the critical temperature, which is contrary to the definition of "critical temperature." While, of course, the formation of the slag requires a considerable quantity of heat, this absorption of heat cannot lower the temperature of the slag, just as ice melting in a beaker of water, and thereby absorbing heat, cannot become colder than 0 deg. C. Such an absorption of heat must be isothermal.

The old-style heat balance of Bell fails because it considers the quantity of heat supplied to the furnace from the hearth to the top of the shaft—i.e., the heat supplied above the temperature of the top gases. Since

there is a continuous, though not necessarily uniform, temperature rise along the furnace axis from the top of the shaft to the zone of maximum temperature in the neighborhood of the tuyeres, and a much smaller drop in temperature along the furnace axis from the zone of maximum temperature to the hearth, there must be at least two zones at what we have been calling the "critical" temperature—one zone somewhat above the zone of maximum temperature and the other zone probably below the tuyeres. The "critical" temperature may possibly be so defined that the quantity of heat developed between the two zones above the critical temperature is more or less definitely related to the output of iron per pound of fixed carbon burned in the hearth. It is entirely possible, though not obviously necessary, that this critical temperature may correspond to the temperature of the freely flowing slag. Mr. Johnson's measurements and observations indicate that this relation is more or less approximately true. No one, of course, can expect to find an exact relation.

The hearth heat, i.e., the quantity of heat supplied above the critical temperature, includes (a) the heat lost by radiation and conduction between the upper and lower critical zones, and (b) the heat required for those final steps of reduction of ore and carburization of iron, and other similar adjustments in composition of molten iron, molten slag, and furnace gases, which occur between the critical zones.

Pittsburgh, Pa.

Some Sources of Error in the Iodometric Determination of Copper

BY CARL E. SMITH

To attain the greatest possible accuracy in rapid quantitative determinations of copper by means of the iodometric method, as often required in commercial analyses of metallic copper and its alloys, several factors must be considered that are frequently overlooked and in treatises dealing with technical analysis are either not emphasized enough or completely ignored.

Sampling

For instance, it is usually recommended in standard manuals to weigh out for the analysis such small quantities of metals as 0.5 gram, or even less. Unless the sample is in a very finely divided condition, which is usually not the case, and well mixed or for other reasons is known to be of uniform composition throughout, it is obviously impossible to obtain by means of such small quantities an accurately representative part of the entire sample. There have doubtless been many instances where results of analyses of parts of the same sample, made by different analysts or even by the same analyst, have differed widely for this reason alone.

Drillings and cuttings of copper products, as submitted for analysis, are often expected to represent the average composition of large lots of material, portions of which may differ considerably in copper contents. There is often so much uncertainty about the accuracy of sampling large lots of materials, even under the most favorable circumstances, that it is all the more necessary that the chemist should not add to a possible error in the original sampling a defective sampling of his own. Even when the sample is in relatively small pieces, the writer has often found it necessary to take 5 grams or more to avoid an error of that kind. When the pieces are large the best way, doubtless, is to cut up the entire sample into small fragments and weigh out a quantity large enough to leave no reasonable doubt that a thoroughly representative portion of the entire sample has been taken.

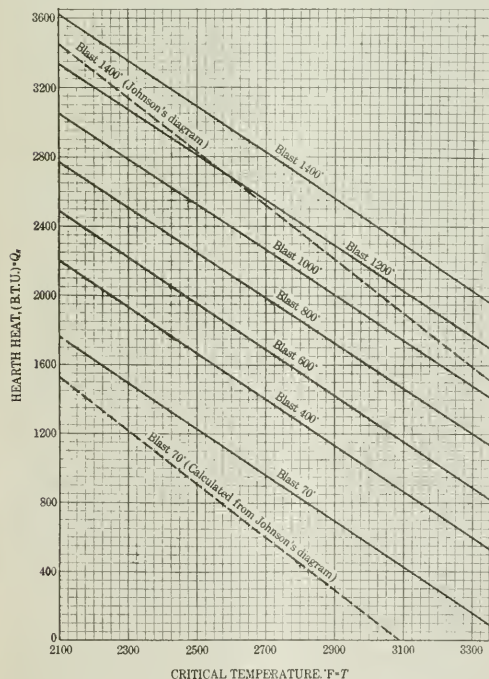


FIG. 1—REVISED HEARTH HEAT DIAGRAM BASED ON 1-LB. FIXED CARBON ACTUALLY BURNED IN HEARTH

As regards the sampling of large quantities of copper, a repetition of the excellent recommendations of the American Society for Testing Materials, made in its Year Book for 1915, may be of interest. For wire bars, cakes, slabs, billets, ingots and ingot bars of Lake and electrolytic copper, in connection with investigations of claims as to metal contents, they are essentially as follows:

"* * * Each party shall select a sample of two pieces. These shall be drilled in the presence of both parties, several holes approximately $\frac{1}{2}$ in. in diameter being drilled completely through each piece; scale from set shall be rejected. No lubricant shall be used and drilling shall not be forced sufficiently to cause oxidation of chips. These resulting samples shall be cut up, mixed and separated into three parts, each of which shall be placed in a sealed package, one for each party and one for the umpire, if necessary. * * *

For sampling copper ingots a Committee on Standard Methods of Analysis, of the American Chemical Society,¹ recommends as follows:

"Select six ingots at random from the lot. Considering three ingots as a rectangular unit, drill one hole in each ingot, one at the center and one at each end of a diagonal of the rectangle. Drill each hole entirely through the ingot, starting from the bottom. Start the drill on the surface sufficiently to remove the oxide before commencing to collect the drillings for the sample. Run the drill so as to prevent oxidation of the chips. Discard all drillings carrying oxide from the 'set,' or burned by the drill. Use no lubricant on the drill, and, if the sample shows oil or grease, remove this with ether. Sift all drillings on a screen with 250 meshes to the square centimeter, in order to remove material which is ground between the drill and sides of the hole. Extract with a strong magnet any iron which may have come from the drill. Keep the drillings in airtight bottles."

Errors in Analytical Procedure

A source of appreciable error may be in the method of dissolving the metal and in the preparation of the solution for titration. One may easily underestimate the loss incurred through a brisk effervescence while the metal is being dissolved in acid, even when the container is covered. For the same reason boiling should be avoided during the removal of the lower oxides of nitrogen, or at any stage of the analysis, for that matter. This is mentioned here particularly because several eminent authorities direct boiling at two or three stages of the operation. While this somewhat lessens the time required to complete the assay, it does so only at the expense of accuracy.

Neither is it necessary or advisable to add bromine, hypochlorite or other agent to convert lower oxides into nitric acid. Indeed, it is the writer's experience that introduction of halogen may be a positive source of error when the copper contains silver, which is often the case. The precipitate of silver halide is gradually decomposed by the nitric acid during subsequent heating, notwithstanding the statements in text-books to the contrary. This decomposition proceeds until the precipitate is dissolved, slowly generating lower oxides of nitrogen and bromine or chlorine. This disturbing factor needs no further comment. In the writer's experience there is no difficulty in completely expelling lower oxides within a reasonable length of time simply by heating the solution below a boiling temperature. That means has been used in this laboratory continually for a number of months with uniformly satisfactory results.

Some other sources of error will be touched upon below.

Details of Procedure Recommended

For metallic copper the writer proposes the following procedure on the basis of assays by it of some hundreds of commercial samples:

Prepare the sample as recommended above. To about 6 grams, weighed to 0.5 mg., and contained in 200 cc. conical flask, add 20 cc. of water, then, through a funnel, which forms a baffle to the spray of liquid produced by the effervescence, small successive portions of strong nitric acid, 20 cc. in all, slowly enough to prevent a brisk reaction. When all the acid has been added and the reaction becomes too slow, warm on a hot plate and when solution is complete, remove the funnel and wash copper nitrate adhering to it into the flask with a little water.

Continue heating just below a boiling temperature until the vapors at the mouth of the flask are free from the characteristic odor of the lower oxides of nitrogen, and continue heating for at least 10 min. longer at the same temperature, to make sure that all traces have been expelled. There is no objection to heating considerably longer, provided no basic salt is formed.

Cool the solution and dilute it to 1 liter in a measuring flask. Pipette 50 cc. into a vessel suitable for titration. Add enough ammonia water to produce a permanent turbidity (4 to 5 drops), then 5 cc. of glacial acetic acid. Dissolve in the solution 3 grams of potassium iodide. (It is not advisable to keep a stock solution of the salt for this purpose, as sometimes recommended, since the solution on standing absorbs oxygen and develops iodate.)

Immediately titrate with 0.1 normal thiosulphate, with constant agitation of the liquid. When most of the iodine is decolorized, add starch solution and complete the titration by adding the thiosulphate very slowly toward the end, which aids in obtaining a sharp end point. A still sharper end reaction is obtained by running in a slight excess of thiosulphate, and titrating the excess with iodine. Of thiosulphate of about 0.1 normal strength 46 to 47 cc. will be required.

In accordance with the observations of Treadwell, it is best to let the thiosulphate solution stand for several weeks before determining its copper value, as it will then retain the same strength for some months, although it changes rapidly during the first few days after it is made.

A standard copper solution for determining the copper value of the thiosulphate, made from copper of known purity, should be prepared in exactly the same way as the solution of the copper to be assayed and the identical measuring flasks, pipettes and burettes should be used for both standardization and assay. It need hardly be mentioned that burettes of small bore and graduated for close reading are absolutely necessary for exact work.

It should also be obvious that suitable correction for variation in volume of the standard solutions, due to temperature changes, cannot be neglected if accuracy is desired. A difference of 5 deg. C. from the temperature at the time of standardization, for example, would otherwise cause an error of nearly 0.1 per cent.

An assay made in the manner described can easily be completed in less than two hours.

Carl E. Smith Testing and Research Laboratory,
New York City.

The General Chemical Company will erect a clubhouse for its employees at Pulaski, Va., the contract having been let for same.

¹The Journal of Industrial and Engineering Chemistry, 1915, v. 7, p. 546.

The Metallurgical Disposal of Flotation Concentrates

BY R. J. ANDERSON

The flotation process has revolutionized the metallurgy of the base metals, particularly copper, lead and zinc, and from recent commercial practice bodes to extend its application to such an extent so as to replace the cyanide process at least in part, if not in whole, in some places. Oil flotation has had a radical influence on both mill design and on smelting operations, particularly copper practice, and the successful disposal of flotation concentrates is an important phase of the new metallurgy. This disposal involves the problems which deal with the handling of concentrates as produced by the different flotation processes and the subsequent smelting of the concentrates. This, then, gives rise to two divisions of the subject; namely, (1) handling of concentrates and (2) smelting of concentrates.

The Handling of Concentrates

Froth Breaking.—Flotation concentrates, *i.e.*, the froth entangling the valuable sulphides (and gangue in subordinate amount) plus water, is an unsmeltable product as such. The first step in the disposal operations requires a breaking of the froth, particularly if it be a mechanical froth, such as is produced by the Minerals Separation, Hebbard-Harvey, Janney or similar mechanically agitated machines. The pneumatic froth of Callow or Towne-Flynn is ephemeral and breaks of itself when removed from the influence of the injected air (although, of course, its stability is influenced by the kind of oil used), and is, therefore, more easily handled. The mechanical froth, however, is thick and more or less permanent, and its disposal has presented serious difficulties.

A common practice for froth breaking, which is quite effective, simply calls for the spraying of water on the froth as it flows in its launder. In a number of instances bucket elevators have proved quite efficacious; the splashing and striking of the buckets causes the froth to break up. At the Herculaneum plant of the St. Joseph Lead Company there have been installed pug-mills for this purpose. In addition, these mills insure a steady stream of concentrate feed to the mixing belt whereby the flotation product is mixed uniformly with the usual feed for the Dwight and Lloyd sintering machines. The method of running the concentrate over tables of the Wilfley or Card type has been tried and is successful in breaking up the froth. Froth may also be effectively broken by the addition of reagents such as acid or lime, or even by adding more oil. In regard to this latter, if an excess of oil is added to a successfully operating flotation unit the froth may be practically "killed." A filter of the pressure type, such as the Kelly, Shriver or other, will break up the froth in the dewatering operation.

Dewatering.—All flotation processes produce a wet, sloppy, frothy concentrate which is extremely difficult to handle and ship unless dewatered. The skillful and economical disposal of flotation concentrates preparatory to shipment and smelting is, therefore, an important problem. In discussing dewatering practice, certain machines have found their way into the mills and certain methods have been adopted which probably embody the tendencies toward a future standard practice. Some of the apparatus used for dewatering includes the following; *viz.*, settling bins, filters—pressure or vacuum, drag-classifiers, screw-classifiers and thickeners.

The practice of settling the froth in bins, while a common one, does not reduce the moisture sufficiently low for shipment by rail unless for short distances. The

mill of the Utah Leasing Company at Newhouse, Utah, has large bins of 200-ton capacity for settling the concentrates. Practically all of the larger plants have come to the use of filters either of the pressure or vacuum type, or both.

The functional utility of the filter lies in its ability to reduce the moisture content of the material treated to practically any desired percentage. Pressure filters of the Kelly type can take the flotation froth direct and perform the function of froth breaking and dewatering in the same operation. The pressure filter is more bothersome to operate, because it is intermittent in action and requires constant attendance. Although the pressure filter can reduce the moisture content to as low as 6 per cent, the vacuum type finds more favor. The vacuum filter is represented by the so-called Oliver and Portland types. This type of filter is not well adapted to the immediate dewatering of froth concentrates because such product will not cake well on account of its high percentage of moisture—60 to 70 per cent and occasionally considerably more. The pulp feed for vacuum filters should have a ratio of 1 to 1. If the froth be first broken and then dewatered in a Dorr tank, the vacuum filter can be used, and it is preferable to the pressure type by reason of its continuous operation and low operating cost. The vacuum filter in practice can make concentrates of any moisture content to as low as 8 to 10 per cent. Where concentrates are to be briquetted, such a low percentage of moisture is not necessary, but should be as high as 15 per cent, or more.

An example cited recently in the current technical literature, which gives a method of dewatering flotation concentrates, is the practice at the Inspiration mill in Arizona. Here the concentrates from the flotation processes and from the tables converge to a drag-classifier; the coarse product from this machine is sent to an Oliver filter and the fine product to a V-shaped settling tank, where it is thickened. The thickened and settled fine from the tank then goes to the filter. The filter cake from the Oliver machine is trammed to a bin and thence loaded into bottom-discharge railroad cars for shipment to the smelter. At the Miami mill in Arizona, the flotation concentrate is thickened in Dorr tanks and the thickened product then conveyed by bucket elevators to a group of 12-ft. x 12-ft. Oliver filters. The caked concentrate is scraped off over a steam-heated plate and then removed to a steel storage tank preparatory to shipment to the smelter.

A type of machine brought out in recent years by one of the Western companies which is applicable to the dewatering of flotation concentrates is the so-called Ovoca classifier. This is a classifier of the screw type. The froth is broken down effectively, giving a continuous clear overflow solution at the weir and a continuous discharge of dewatered concentrate—moisture 15-25 per cent. A screw dewaterer is in operation at the Oneida Stag mill at Idaho Springs, Col. At this place the flotation concentrates plus the table concentrates are passed through a screw dewaterer and the two are thus mixed and dewatered in one joint operation. The dewatering machine removes from 60 to 70 per cent of the slimes with the coarser table product, and the overflow removes the balance of the slimes. This latter goes to settling boxes and is there settled and thickened.

The practice of washing flotation concentrate is a development as yet new in American practice. The leading consideration in washing is the removal of part of the insoluble matter whose presence in the final concentrate detracts from its grade. Washing is employed at a New South Wales mill in Australia. Here the flotation product is led into settling bins and washed by means of spray water playing on it as it enters. The effect of this is to disintegrate the froth so that the

sulphides sink to the bottom and at the same time part of the floated gangue is carried over the lip by the moving stream of water.

Drying.—This is an important consideration in flotation practice, particularly if the concentrate is to be shipped long distances. The mills, unless indeed they be very large mills with their smelter on the ground, are often as far as 750 miles from the smelter which consumes their concentrates. Every pound of water in the shipped product has to be paid for as freight, hence the moisture content should be low. Often a wet concentrate is not a marketable product as such, and always excess moisture adds extra cost to the labor of handling. The advantages accruing from dewatering and drying lie in the following; viz., (1) by reducing the moisture and thus obviating the paying of freight on water, (2) by preventing the loss of slimy concentrates due to leaking tanks and cars, and the messy sloppage which comes with the handling of wet material, and (3) by avoidance of delay from the freezing of concentrates in cold weather. A difference of 3 or 4 per cent lower moisture content may mean the saving of many dollars in the costs of loading and freight.

The practice of handling flotation concentrates at the Engels mill in California is interesting in its uniqueness. The floated concentrate is first removed to a settling tank outside of the mill building for settling and thickening; the thickened product from here goes to an 8-ft x 8-ft. Oliver filter, which makes a cake containing 10 to 12 per cent moisture. On account of the long distance which this concentrate has to be shipped, namely, to the Garfield smelter near Salt Lake City, it is desirable to reduce the moisture to the loss-by-dusting point—about 5 to 6 per cent. To accomplish this an unused drag-classifier was being remodeled so that heat could be applied beneath it; the dried concentrate is then sacked in canvas bags and loaded via tramway onto a caterpillar tractor for conveyance. Part of the journey to the railroad is accomplished by motor trucks where the roads are good. At the railroad the sacks are emptied into railroad cars for shipment to the smelter.

The Smelting of Concentrates

The new conditions imposed by the character of the flotation concentrates forced a change in the details of furnace operation, and hence the metallurgical treatment of such concentrates is an entirely new subject. In the case of copper concentrates, the product is improved in copper grade and simultaneously in iron and sulphur and impoverished in silica and alumina, when compared with either direct smelting ore or intermediary mill concentrates. The amount of flux required is then correspondingly lessened as the charge is usually more fusible. The extreme fineness; i.e., slime character of flotation concentrates, produces a product in which the alumina (if it be present) is in a colloidal condition and no clay is needed for a binder in briquetting; at the same time, its fineness makes drying and filtering difficult, and its wetness makes briquetting impossible without dewatering. At the Braden mill, Chile, elsewhere mentioned recently, the table concentrate was only fairly fine but was very infusible, due to high silica and alumina; on the other hand, the flotation concentrate was not only very fine and wet but also of a lower silica content which made it more easily fusible.

In regard to the smelting of flotation products there are several methods which have been in commercial use; namely, (1) direct smelting (2) sintering and smelting, (3) nodulizing and smelting, and (4) roasting and smelting.

(1) *Direct Smelting.* This was and still is in part the practice at the Braden mill, Chile, South America. The concentrates were settled but not filtered (this was

previous to the arrival of the filter presses) and charged into the blast furnaces direct. In spite of the fact that the charge was more fusible than before the coke consumption increased considerably. The reason for this was that extra heat was required to evaporate the moisture, and, further, that the wet charge "blanketed," so to speak, and was more or less impervious to the blast penetration. The practice of drying and preheating concentrates preparatory to furnace smelting shows an economy of fuel over charging raw concentrates.

(2) *Sintering and Smelting.* Sintering of flotation concentrates before smelting is comparable to any common sintering operation. At the Herculaneum plant of the St. Joseph Lead Company, already alluded to, the lead flotation concentrate is mixed with the lead table concentrate on a mixing belt, and the mixed product is deposited to sintering machines—Dwight and Lloyd. At the Braden mill, mentioned in the foregoing, the sinter plant consists of four units; each unit is simply a concrete box 50 x 4 ft., on top of which is placed a cast-iron grate similar to a boiler grate. An exhaust fan creates a strong down-draft. The concentrate, spread on the grate in a layer 4 to 6 in. in thickness or less, is ignited by a layer of shavings or sawdust. Once started, the charge roasts from the combustion of the sulphur and becomes agglomerated into a hard cake which is broken into pieces 6 to 8 in. in size. The sintered product thus broken is ready for the blast furnace.

(3) *Nodulizing and Smelting.* Nodulizing is a continuous process which reduces, by roasting, the sulphur content of the concentrates and produces nodules or balls of the roasted charge. A nodulizer consists of a revolvable steel tube lined with fine brick, similar in appearance to a rotary drier of the Ruggles-Coles or other type, 8 ft. to 10 ft. in diameter and from 50 ft. to 120 ft. long. The tube is slightly inclined with a slope of about 1 in. per foot toward its discharge end. Firing is accomplished with oil, gas or powdered coal. In the nodulizer, the concentrate is heated by the firing and also by the burning of the sulphur in part: the charge soon assumes a sticky, viscid consistency and, due to the revolving, rolling motion of the tube, is "balled" into nodules of varying sizes, which are discharged red hot and thence fed to the blast furnace. The nodulizer thus dries the concentrates and reduces the sulphur content to any desired amount pendant on the length of the tube and its diameter; i.e., the time necessary for a unit charge to pass through the tube. The smelting of the nodulized concentrate imposes no new conditions on normal blast furnace operations.

(4) *Roasting and Smelting.* This is best depicted by Anaconda practice as set forth at length in recent technical literature. The installation of flotation at the Washoe Works necessitated the roasting of an augmented tonnage of sulphides, and consequently the roasting plant had to be enlarged. The roasters are multiple-hearth furnaces—seven hearths in all—of the MacDougal type having a shell diameter of 25 ft. and an inside diameter of 23.5 ft. The flotation concentrates and the fine table products are mixed together, thus insuring a uniform roaster feed. The hot calcines are charged to reverberatories. The practice of firing reverberatories with powdered coal has shown a fuel economy over blast furnace smelting; moreover, the reverberatories demand a fine charge so that the development of coal dust as a fuel, when applied to these furnaces, has come in proper time to be of great aid in smelting the fine product produced by flotation.

Resumé

Some miscellaneous considerations arise in connection with the disposal of flotation concentrates, hitherto

not mentioned. In regard to the matter of the cleaning and reclaiming of concentrates, two cogent factors enter into the solution of this problem; to wit, leanness or richness of the ore or slime feed and remoteness or proximity to smelters. Here it may be said that on rich feed or where a relatively low-grade concentrate can be consumed economically in a nearby smelter, only one cleaning is necessary; but where a high-grade concentrate with small amount of insoluble is demanded, the dual clean and reclean method is expedient. The matter of the grade of a concentrate may be markedly affected by unlooked-for conditions, as witness the experience of three of the operating companies at Broken Hill, Australia. Before the present great war, a shipping concentrate to Germany demanded a grade of some 47 per cent zinc; any grade below this was subject to penalty. The so-called Broken Hill Associated Smelters Proprietary Company which now has control of the smelting plant at Port Pirie, a distance of some 250 miles from the mines, is taking concentrates as low as 40 per cent zinc.

Still, the production of a high-grade shipping concentrate even for comparatively short shipments usually proves economical in the long run through the savings in freight.

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Mass Screening with Flat Screens

BY EDWARD S. WIARD

Since power-driven machines are more important than stationary or hand screens, and since the power machines have arisen from the attempt to duplicate the motions used with the latter, an inquiry into the results obtained by the motions produced in hand-screening will yield information of value for obtaining the proper ele-

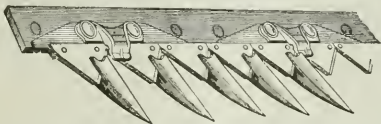


FIG. 1—CODING OF HAND-ACTION IN REAPER

ments for machine screening in mass. The steps by which the body, or more particularly the hands, aided by simple tools, perform mechanical operations, and the thought of the inventor that transfers these steps into mechanical equivalents, have been termed by one writer, "coding."

As an example of coding there is the operation of cutting grain with an edged tool. To do this efficiently by hand, the stalks must be struck with a single hand by a sickle at a point close to the ground; or else a bundle of the stalks must be grasped in one hand and struck below this hand with the sickle in the other. In either case the stalks are held sufficiently immovable so that the cutting blow can be effective. In coding these steps for application in a reaper, the first point which will be recognized is that the single sweep of the sickle is too limited in radius; or if the sickle be made sufficiently long, resembling a scythe, the forward advance of the reaper would cause certain portions of the area swept out by the scythe to be passed over during the drawing back period of the blade. Such a blade would also be very dangerous, and the danger would increase the more rapidly it moved, a very fast motion being imparted to it to reduce the uncut area due to the advance of the reaping machine. But the principal objection to a long blade would lie in the requirement that it would have to hew close to the ground to obtain the hold necessary

for efficient cutting, and the inequalities of the surface would prevent this if it were incorporated in a reaping machine.

The universal coding of the hand action for reapers is shown in Fig. 1. A fixed member holds the stalks against a reciprocating knifed saw blade. It is said that Obed Hussey who, with Cyrus McCormick, invented the modern reaper, originated this element; but it seems older than this, an English patent having the element prior to the year 1800, while Hussey's patent is dated 1833.

Another example of coding, somewhat farther afield from hand action, lies in machine sewing. The simplest hand stitch is of the type where the needle with the thread is forced through the fabric from side to side. This action has been imitated in certain classes of stitching machines which employ a double pointed needle, the eye being in the center. The turning of a point of a needle with an eye in the butt back to the original position, as is done in hand sewing, offers insuperable difficulties from a mechanical point of view. Hence, sewing machines are of two types, in both of which auxiliary means are employed below the surface of the fabric or the surface on which the fabric is laid, to secure the loop forced through by the needle.

It may be remarked before closing this subject of coding that patents fall roughly into three classes. In the first, hand or bodily actions are strictly imitated. In the second, the results of hand or bodily actions are obtained, but mechanical means are introduced which are impossible to the hand or body. In the third class of patents, results are achieved which are entirely outside the domain of human muscular movements. An example of the first class is the steam-power hammer. The sewing machine and shoe-making machinery exemplify both the first and the second classes. The invention of the electric light, caborundum, etc., are examples of the third class. The intelligence displayed in the three orders of invention are about in the order of their statement, but so far as the sum of human good goes the first two classes preponderate.

Mechanical Screening Coded from Hand Actions

The operation of mechanical screening is directly the outcome of coding hand actions with a hand screen though often the thought of the inventors as disclosed by patent office records is obscure.

So far as dry hand-screening goes with fairly heavy material, the best result is obtained by a sidewise, slightly rocking fast, uniform motion from right to left, continued for three to ten strokes, followed by tapping sharply on the working bench. With coarse material, tapping is not so necessary. The sharp, uniform motion prevents the grains from partaking of the motion of the screen, and the latter slides under the grains. At the end of each half stroke the mass on the screen tends to pile up against the side of the screen; and to prevent this and spillage, the screen is slightly tilted, an operation which is done quite naturally. A rotary motion of the screen is of very little effect since there are retardations and accelerations in this kind of motion, and the grains have a chance to take up the motion of the screen. No screening will be done and time will be lost.

The next thing which will be noticed in hand screening is that a certain depth of bed gives the greatest capacity. Why this is so, is primarily because of the time lost in transferring small masses to the screen. As the amount placed on the screen increases, a point is reached where the operation of screening is unduly prolonged; that is, a certain depth of bed is reached where complete screening action ceases. The finer the material fed to the screen, the shallower must be the bed to ob-

tain the best screening action. When screening in a mass, the principal action is an interstitial one which brings the fine grains to the screen first, and successively coarser ones, so that with prolonged shaking the finest particles go through first, followed successively by the coarser.

To understand this action reference should be made to Fig. 2 which shows diagrammatically the amount of interstitial opening, or amount the grains part from one another under the shaking action. A-B would represent the amount of opening at the top of the mass of material on the screen, while at O where the mass is in

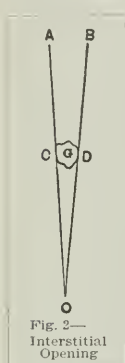


Fig. 2—
Interstitial
Opening

contact with the screen the amount the grains part from one another is zero, or very nearly zero. A particle such as G would pass down through the interstitial opening thus created to the position C-D, and evidently finer particles can proceed down farther, until a particle of no sensible diameter would arrive at the surface of the screen. The first few shakes of the screen would complete this action, giving the



Fig. 3—
Gradation of
Particles

mass on the screen the appearance shown in Fig. 3. To some extent this regular gradation, from coarse at the top of the mass to fine at the bottom, is altered by the position of the grains as they occur in the mass at the beginning of shaking; but the more prolonged the shaking the more perfect will be the gradation, for the coarse pieces are brought to the top of the mass. With any range of size, however, if the bed on the screen be of too great depth, motion tending to open the grains at points near the screen ceases. So long as there is interstitial action, screening with a deep bed will yield commercial results which approximate those obtained by screening with a bed one grain deep.

Deep and Thin-Bed Screening

To put the matter in the simplest form, let the motion of a mechanical flat screen be such that the undersized grains advance in a mass 10 grains deep. Then evidently grain number one, counting from the top, will have no chance to come over an aperture until grains 2, 3, etc., have been eliminated. If the motion of the screen advances the material at an amount per stroke such that one grain of undersize is eliminated at each stroke, then grain number one will have to pass over ten apertures before it can go into the undersize. If the material be fed one grain deep, all the grains under the same conditions, as has already been recited, will be eliminated at one stroke and the capacity per unit of surface will remain unchanged. The disadvantage of deep-bed screening for precise work lies in the fact that as the bed advances toward the discharge edge of the screen it becomes, with respect to undersized grains, more and more to consist of grains near the size of the openings. Undersized grains not in contact with the screen will pass into the oversize due to disadvantages of position.

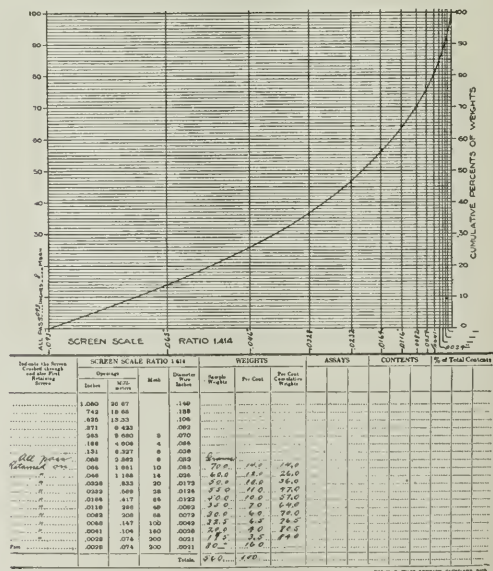
A minor advantage of having the bed as thin as possible lies in the ability to make the motion of the screen such that the grains in their passage over the screen will be thrown into a multitude of axial positions which will be helpful in eliminating the undersized grains if

there be much irregularity of shape. Cork particles, while presenting very irregular surfaces, are roughly cubical; and if a screening device were used which gave them an upward component of motion as well as a forward one, air currents would be created through the apertures tending to buoy the undersized particles and prolonging their elimination. Consequently, for grading cork various types of bolting machines are used in which the motion of advance is all in one plane. If the motion of the screen be such as to create an active tumbling about, some products would be injured by breakage or crumbling. As examples of this may be mentioned green peas and friable material such as coal, etc. Blinding of the apertures of a screen occurs both in wet and dry screening.

Where crushed material is being screened it will be evident from inspection of the curve shown in Fig. 4, that as the weight increases from size to size the more finely the material is crushed, the number of particles increases much more rapidly than figures which would be proportional to the cube of the reciprocal of the diameter. On the other hand, the number of apertures per unit of screening surface increases only as the square of the reciprocal of the size of the aperture. Consequently with finely crushed material there is always a greater number of particles of very nearly the size of the aperture which will become jammed therein, producing blinding. Again, in reducing material by crushing, as the sizes become successively smaller, types of machines have to be used in which grinding actions become increasingly evident. This tends to put many faces on the grains, thus affording them more opportunity to become firmly lodged in the apertures of the screening machines. Means for reducing blinding will be discussed at a later point.

Advantages of Wet Screening

The majority of the products occurring in the grading industries are produced by machines which treat them dry. In the ore milling industry of the West, however, there are some advantages in screening the ores wet. Wet hand-screening is found to be very effective.



tive for fine material, but where the coarsest particle to be screened is $\frac{1}{4}$ in. or larger, screening can be done just as well dry as wet. The only advantages of wet screening are the washing off of a coat of dust which may adhere to the grains, and the use of water for transporting the oversize and undersize products from point to point in launders. This permits of a cheap mode of transportation and much less loss in head room.

Now in hand screening in a suitable vessel to hold the undersize and the water to aid in the operation, the thing noticed at once is that unless the mass on the screen is occasionally stirred with the fingers, little or no screening action takes place. Again if the screen is pushed down too deeply in the water the effect is not so good as where it is pushed down to a position where the bed of particles is barely or slightly submerged. An up-and-down or jiggling motion of the screen is not so effective as this movement followed by sidewise movements. The jiggling movement alone brings the coarse particles to the screen while the fine go to the top, but it is very effective in keeping the bed loose. The sidewise motion, while very effective for bringing the fine particles to the screen, has a tendency to cake the bed down on the screen, when of course no further screening action ensues. The principal good effect of the jiggling action is the loosening one, followed by the draining away of the water through the apertures carrying with it undersize particles. If the screen be too deeply submerged the water cannot drain away under the jiggling strokes and this useful effect is lost.

In coding the hand actions great difficulties are at once encountered. If it were possible to feed the grains in a mass one grain deep, which is impossible with fine material, submerged shaking screening would be in no wise superior to dry screening. Consider a flat screen submerged in a vessel of water, and to which to-and-fro movements are imparted to advance the material. If the apparatus be started with the proper amount of submergence so that the bed is partly or just submerged, the action of the screen will create waves which will destroy the stratifying action, bring a considerable volume of water above the bed, cause the latter to cake down on the screen and entrap the water above it. If the screen be made stationary, and means be provided such as a drag for moving the material along the screen, then the useful interstitial or stratifying effect is lost and the effect is no better than with dry screening. The loosening effect of a jiggling stroke introduced occasionally is also wanting in this type of apparatus, and to introduce it would add much extra complication.

Other difficulties which are encountered in coding the hand actions, and which are wanting in the latter, are the disposal of the under- and oversizes. If the undersize be allowed to flow from the bottom of the tank, the opening must be sufficiently large to prevent clogging and this will require excessive amounts of water. If mechanical means are used to remove the undersize, it adds to the complexity of the design. If a flat screen be employed, it is quite evident that much of the water will spill over the end of the tank unless some special form is used. Thus J. M. Callow's patent (788,246, April 25, 1905), shows a shaking screen with a small upturned, hinged portion at the discharge end, and evidently a screen with an upturned curved portion at the discharge end would give the same effect. Wet screening without submergence on flat screens is very inferior to dry, because the water drains away quickly, leaving a balled-up, sticky mass, which is difficult to progress over the screen. The overcoming of this action by the Callow belt screen marked an advance in the art.

When all the difficulties are stated, however, there

seems to be no reason why a perfectly successful submerged screen might not be devised which would be very effective and have large capacity.

Mechanical Features of Screens

Screens may be divided into two types: First, those on which the feed advances in a more or less horizontal sheet or in an inclined sheet; and second, those in which a revolving motion is imparted to the feed.

Under the first type there are the following principal varieties. (a) Stationary, and flat or inclined shaking screens. (b) Endless-belt screens, both horizontal and inclined. (c) Rotary flat screens, the means for advancing the feed being centrifugal force. The surface of screens of this variety is a plane, of more or less concave annular surface. (d) Gyratory screens. These have flat surfaces, and in the flour-mill type, or bolter, the screening surface is rotated in a horizontal plane. The Cox gyratory screen, intended primarily for coal, is mounted on double cone rollers which give a rocking motion to the gyratory movement. (e) Batteries of corrugated cylinders mounted with their axes parallel and in a horizontal plane, have been proposed and used for grading coal or other friable material. The cylinders rotate in a direction to advance the coal, and the undersize falls through the spaces created by the corrugations which match one another on the various cylinders. By diminishing the depth of the corrugations a series of gradings can be obtained. (f) Revolving vertical cones, or stationary cones fed by a revolving horizontal plate.

The second type includes all varieties of revolving screens, or trommels, which are usually placed with their axes horizontal or slightly inclined; although highly inclined cones have been used for this purpose.

The flat shaking screens are of two kinds: those employing perforated metals or screen cloth and those having shaking bars of different shapes. Where a backward and forward motion is employed to advance the material it must be of a differential character or else the screen must be inclined. One way of securing differential is to have the screen moved by a pitman through a pair of toggles, one seat of one of the toggles being fixed and the other connected to the screen in such a way that when the toggles are at the lowest position the screen is at the extreme forward point and moving forward fastest. The simplest differential is one that imparts to the screen an accelerated forward motion and a retarded return. This motion gives the grains a chance to partake of the motion of the screen, while on the quick return they continue to advance. If the motion of the screen was uniform backward and forward it would be impossible for the grains to pick up the screen motion and they would merely roll or slide over the screen under the actuating movement. If a bumping device be used, the kind of motion toward the bumper is not of much moment, since with any kind of forward movement the grains will have picked up some forward movement; and on the screen being brought up sharply against the bumper they must continue to advance. The disadvantage of the bumper device is that it sets up destructive shocks in the screening mechanism.

Counterbalanced Shaking Screens

It is quite essential that shaking screens be balanced to prevent destructive vibration to the framing. This can be done by counterbalancing as shown in Fig. 5, the only requisite being that there be an amount of momentum in the counterweight equal to that of the screen. By increasing the length of leg of the counterpoising portion of the system the counterweight can be

decreased to any desired degree, for evidently in any case the weight of the screen through the space passed over, or its velocity, must be equal to the weight of the counterpoise through the distance over which it passes, or its velocity, during a stroke. Theoretically, of course, the balanced system having twice the mass will require twice the power to actuate, but this is more

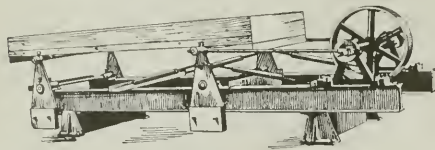


FIG. 5—BALANCED SHAKING SCREEN

than compensated by less friction due to unbalanced thrusts on the bearings or pivots of the screening machine. Another mode of balancing is to have two screens moving in opposition to one another. All grain-cleaning separators, Fig. 6, are thus arranged in pairs, and the remarkable smoothness and freedom from vibration of flour-mill or grain-elevator separators is noticeable at once to an observer. The Coxé shaking grizzly, which is shown in Fig. 7, has two sets of bars moving backward and forward in opposition to one another, thus securing almost perfect balance. The bars have an elliptical motion, the longer axis being forward and the shorter an upward component. These bars are much used in the anthracite coal regions of Pennsylvania and on this class of material they have a capacity of 3.65 tons per 24 hr. per square foot of bar area. Advance of oversize grains is secured by their straddling two bars of a set which are moving forward at any time; and when bars of the second set come up through in their forward motion, they also carry the particles ahead an additional amount, and so on until discharge.

Disadvantages of Flat Moving Screens

Plain revolving flat screens with the screening surface in a horizontal plane have the disadvantage that the motion of the grains from the center where they are fed to the periphery is very nearly along a radial line; and as the motion of the grain accelerates very rapidly, the chance of its falling through an aperture consequently diminishes as it proceeds toward the periphery. To offset this, centrifugal screens are sometimes made with concave curved surfaces to retard the motion, the oversize spilling over the lip of the screen

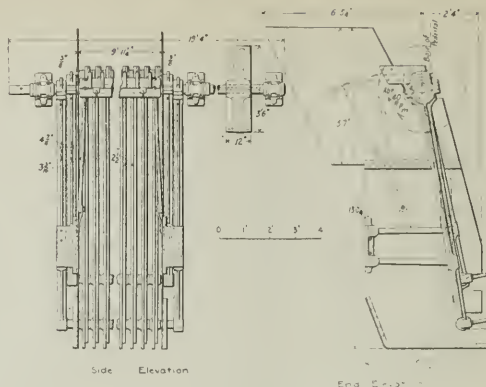


FIG. 7—COXÉ SHAKING GRIZZLY

which is curved up sharply at the discharge edge. Plain rotary screens of this type have an advantage in that they need no balancing; but the tendency of the grains to be continually in motion is not good from the screening point of view and not so good as in a reciprocating screen where the grains have a chance to come to rest at the end of the stroke. Also, where the grains are not isometric, longish and flattish grains have very little chance of disposal in the undersize where they may belong. Gyratory types, of which the best examples are probably the bolters used in the flour-milling industry, are essentially flat screens arranged in parallel batteries, and to which a gyratory motion is given. The outlines of the machine are rectangular when screens of this shape are employed, or cylindrical when circular flat screens are used.

Means for balancing gyratory screens can be made quite simple. Thus the bolter of Fig. 8 is supported on two eccentrically placed pins of the flywheels A-A which drive the mechanism. These flywheels carry counterweights as shown in Fig. 9 of the flywheel. In the gyratory devices, while the moving force is centrifugal the grains do not proceed by such direct paths to the periphery of the screen, the motion of the particles being elongated ellipses the long axis of which is directed toward the periphery. With a gyratory motion every point describes a small circle. Quite evidently if the speed be too great the grain will not partake of the motion of the screen, and at the end of each stroke it will be practically in the same position with reference to a point on the screen on which it rested at the beginning. If the speed be too low the particle will partake of the screen motion exactly, and at the end of a stroke will be in the same position as before. Between these two limits will be found the one giving the best screen effect, for evidently as the speed is increased between these limits, the centrifugal or discharging effect will increase; but if this be too great the grains will have little or no chance in passing through the apertures. Gyratories give a greater length of path without reducing the rate of advance. They have a speed of 130 to 180 r.p.m.

Gyratory devices of the bolter kind are advantageously used in flour milling, for the gentle rubbing action of the silk on the broken wheat berry tends to rub the flour through the sieve. Bolters are also used for grading ground cork, for reasons already explained.

Merits and Demerits of Revolving Screens

Revolving screens are made in cylindrical, conical or polysided shapes. The conical or pyramidal screens

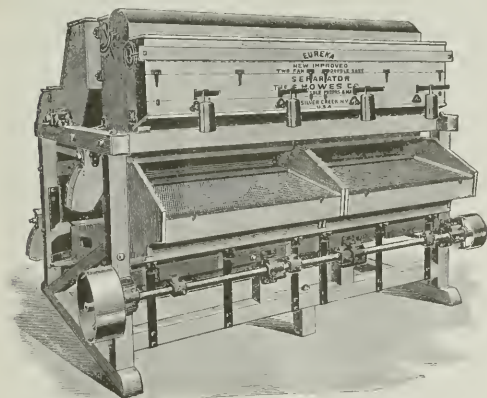


FIG. 6—ARRANGEMENT OF FLOUR-MILL SCREENS IN PAIRS

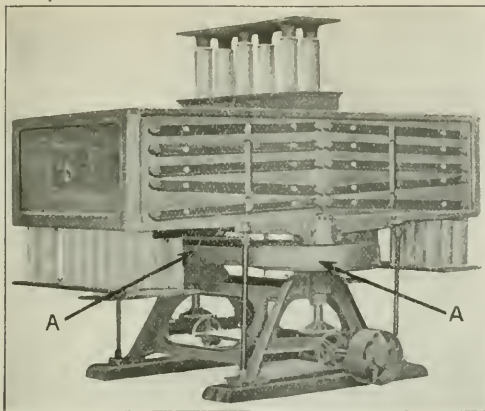


FIG. 8—BALANCED GYRATORY SCREEN

have the advantage that the axis can be placed horizontal; but the disadvantage is that the screens have to be made in a special shape which involves complications in securing the screen to the frame. With practically all horizontal or nearly horizontal revolving screens, the screen proper is supported on spiders and this in turn on a central longitudinal shaft resting in bearings. If the frame of the screen be such as to require a conical clothing, the tires of the spiders must be inclined to the spokes; and if the hold of the screen cloth or plate be by friction, as it is except with the pyramidal shapes, there will be more tendency for the screen to become loose than with cylindrical forms.

The conical and pyramidal shapes can scarcely be said to be an advantage, for there is no gain in head room by their use; and since the best method of drive is through bevel gears, the screen with inclined shaft is at no greater disadvantage on this point than one with horizontal shaft. If the material to be screened has sufficient hardness to produce rapid wear, the spiders must be frequently renewed; and in the case of conical or pyramidal trommels this entails keeping on hand a large stock of spiders of different sizes. The conical and pyramidal shapes have the further disadvantage

that they have less screen area for the same room occupied in housing. A conical screen 6 ft. long and 36 in. diameter at the discharge end will, with a taper of $1\frac{1}{2}$ in. to the foot, have a diameter of 18 in. at the receiving end, and the area of screen surface will be about 6158 sq. in. A cylindrical screen 6 ft. long and 36 in. diameter, and whose housing will occupy no more space than that of the conical screen, will have 8142 sq. in. of screening surface. The largest pyramidal screen of six sides which can be enclosed by the truncated cone will have 5864 sq. in. of surface. But the diminished screen surface will be more serious than indicated by the figures, since at the angles there must be frame members and these will reduce the net area 5 or 10 per cent. I have not taken into account the blind

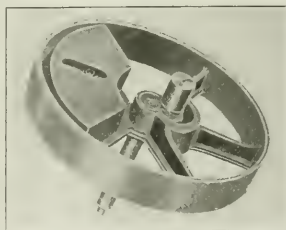


FIG. 9—COUNTERWEIGHTED FLY WHEEL

areas produced by intermediate spiders in any of the cases.

Friction-Roller Drive for Revolving Screens

The usual means of support has been stated to be by spiders and shaft. Dry screens have, however, been supported on four friction rollers or by two rollers and a shaft and gudgeon. At first thought the mounting of the screen on friction rollers would seem to be the ideal way of supporting it. The housing can be made very nearly as simple as for revolving screens supported by central shaft. All the wear comes on the screen surface proper, there being no necessity of replacing worn spiders from time to time, a condition which arises when screening rock and ore. If a wet screen be employed the water may be introduced inside the screen, and not on the outside as must be done with screens with spiders. When the water is introduced outside, most of it is wasted, and often does harm, as in grading ores for separating machines.

The simplest form of friction roller screen would consist of two narrow rings to which would be secured the screen cloth or plate, and four friction rollers. The rollers might be single or connected in pairs by shafts. To drive this mechanism, power would have to be applied to a roller or pair of rollers, motion being given to the screen through frictional contact. Such a means of transmission, however, would be impractical; for even assuming that the only power consumed would be for overcoming the friction in the roller bearings, and further that the screen is perfectly balanced at all points in its circular motion and that hence when the screen is in motion no power is required to rotate it, the starting torque would be sufficiently great to cause the tread rings to slip on the rollers.

It is common to drive these screens either through an enveloping ring with sprocket or gear teeth and by a sprocket chain and pinion, or a gear pinion, or else through a bevel gear. The advantage of the first two modes of drive is that there is a clear space through the screen from end to end; while with a gudgeon and bevel-gear drive, slots must be cut through the sides of the gudgeon to permit the oversize to discharge, and as the gudgeon is a fixed piece this portion will have to be renewed from time to time at some expense owing to wear. On the other hand, the gudgeon arrangement permits of somewhat lighter details, the bevel wheel being of small diameter and affixed to the face of the gudgeon, and in a position where it is less likely to be attacked by grit and dust than the form of drive employing an encircling driven wheel.

Relative Power Consumption of Revolving Screens

The four-wheeled friction mount consumes more power than a revolving screen supported on shafts, or one employing two friction wheels and a shaft and gudgeon. With imperfect lubrication such as obtains with plain bearings lubricated by grease cups, the

power consumption of the central bearing is $\frac{fWN}{2}$

which evidently increases as the diameter of the shaft, other things being equal. In the formula, D is the diameter of the shaft in fractions of a foot, N the number of revolutions per minute of the shaft, f the coefficient of friction, and W the pressure on the bearing.

If H' be the horsepower consumed by a screen of weight W , revolving on friction rollers at N revolutions per minute, and H be the power consumed by friction of a screen of the same weight revolving on a central bearing, also at N r.p.m., then

$$\frac{H}{H'} = \frac{D'}{D'' \cos^2 \theta}$$

where D' is the diameter of the revolving screen, θ one-half the angle made by lines passing through the center of the screen and the centers of the friction rollers, and D'' the diameter of the friction rollers. In this formula the factors of the size of the shaft of the friction rollers and the central shaft are eliminated by making them of the proper proportions to support the same load. In the derivation of this ratio also, the resultant forces acting on the bearings are assumed to be in the line of action of the weight of the screen, in the case of the central shaft; and in the case of the friction rollers, in the lines of the components of the weight. They vary from that line by an angle whose tangent is f , the coefficient of friction.

It will be seen at a glance how much more power is consumed in bearing friction with friction rollers than with a central shaft, which is contrary to common belief. The confusion of thought results from reasoning by analogy from the type of bearing which used to be more commonly employed than at present; for example, where a shaft was mounted on a pair of friction rollers placed as close together as possible; for, as an inspection of the formula will show, the closer the wheels are together the less will be θ and the greater the value of $\cos^2 \theta$, or, the less the numerator and the less consequently the value of H . Such a type of bearing was commonly used on grindstones. Here, if the shaft was 0.5 in. diameter, the value of the numerator would be 0.354. If the friction wheels were but 3 in. in diameter and θ was 30 deg., the value of the denominator would become 2.25; or the ratio H to H' would only be about 1/3, making of course an appreciable saving in power.

Denver, Col.

Corrosion and the Engineer*

BY W. H. WALKER

In the valuable contributions of Dr. McCullom and his co-workers at the Bureau of Standards upon the corrosion of iron structures when buried in the ground, a terminology is employed which is very useful in discussing the damage occasioned by stray electric currents, as contrasted with that caused by the natural corrosion of the iron unaccelerated by an external electromotive force. But while it is logical to call the first type of corrosion "electrolytic," because induced by the flow of an impressed electric current, it is, however, illogical to describe the latter type as "self-corrosion" because of the unavoidable inference that it is not electrolytic, but is purely chemical in its nature. It may possibly be due to this lack of a clear conception of the mechanism of natural corrosion on the part of the electrical and mechanical engineers that is due the fact that they have displayed so little interest in the subject, and have so tardily availed themselves of the knowledge of the phenomena now at their disposal.

In dealing with problems of corrosion the engineer is satisfied if he can explain a phenomenon by stating "that a galvanic cell is set up." Thus a piece of coal in contact with an iron plate or a bit of mill scale on a pipe will cause a pit to form "because it sets up a galvanic cell." From a chemical point of view both the coke and the mill scale are perfectly inert; how then can they cause galvanic action—what rôle do they play in the solution of the iron which produces the pit?

Eight years ago it was my privilege to present before this society a paper on the function of oxygen in the

corrosion of iron¹ in which I offer an explanation for the galvanic action of such inert bodies, and made some applications of the facts described to general engineering practice. Time has shown that the conclusions here drawn were correct. But obviously this paper was not so clearly written, or the facts were not so convincingly told as to attract the attention of the engineering fraternity to it, or at least to occasion any discussion of it. Engineering magazines continue to publish lengthy articles upon the pitting of boiler tubes, the rusting of water supply systems, the red water plague, anti-corrosion compounds and the like. These papers described the symptoms and generally prescribe a cure, but say never a word as to the cause of the trouble.

What would be thought of the medical profession, for example, if it continued to write only regarding the drugs to use in a case of typhoid fever but did not interest itself in the cause and its removal? As a matter of fact, this is an age of preventive medicine. We sterilize the water and inoculate the man in order to prevent the malady. Not so the engineer. He continues to drug his boiler or physic his hot-water-supply system in a vain attempt to cure the disease, but takes no steps to prevent it. He gives whiskey and quinine to help a neurasthenic, when luckily he cures a bad, but unsuspected, case of chills and fever.

Within the last few months there was presented before our largest national engineering society by an electrical engineer a paper which contains data exceedingly important to the profession and which are none the less valuable because old. We gladly recommend this paper² to all who are interested in the corrosion of steam boilers, especially the truly novel portion which consists in recommending a constant observation of the water in the boiler itself, by the engineer in charge, and not simply a study of the feed water alone by some absent chemist. However, the paper would have been increased in value manifold if the author had studied his problem from the point of view of the cause of his trouble and showed the existent relationship between the cause and the cure. In fact when he essays to mention a cause he falls into grievous error. For example, he states: "but it is very evident that the low osmotic pressure of distilled water is the direct cause of the corrosion." Now of all the factors influencing corrosion osmotic pressure from whatever source is the least active—is in fact practically negligible.

Corrosion is an electrolytic phenomenon and can be understood by electrical engineers on purely electrochemical grounds. It takes place at ordinary temperatures only in the presence of water through the reaction



This means that a metallic iron atom electrically neutral interacts with two hydrogen ions present in the water and which carry electrical charges; the result is the production of an iron ion which takes up the two electrical charges from the hydrogen ions and the deposition of two atoms of hydrogen. Energy is lost to the surroundings and appears as electricity and heat.

The factors which influence the action are, first, the solution pressure of the iron. This is constant for all samples of iron under constant conditions, but may be influenced by a number of agents. Thus the immunity of iron to corrosion in solutions of chromic acid is undoubtedly caused by the passivity of the iron—a thing which, whatever its true nature, is equivalent to lowering the electrolytic solution pressure of the metal.

The impression of an external emf. may also be considered as equivalent to a change in solution pressure.

*A paper read before the New York Section of the American Electrochemical Society in joint session with the American Institute of Electrical Engineers on March 10, 1916.

¹ELECTROCHEM. AND MET. ENG., vol. VI, p. 492.

²A novel method of handling boilers to prevent corrosion and scale. By Allen H. Babcock. Am. Soc. Mech. Eng. 1915.

This may be either positive or negative in its direction. If the potential employed be mechanically generated, we speak of it as "stray currents," but if electrochemical in its origin, it is described as the accelerating or retarding effect of other bodies. Thus iron, which itself is incapable of corrosion when imbedded in concrete, is severely attacked if its solution pressure be sufficiently increased by having superimposed upon its own potential, an external emf. due to stray currents. On the other hand the potential of iron may be so depressed by an impressed emf. due, for example, to the solution pressure of zinc, that the iron in contact with zinc will not corrode.

Second, the *number of the hydrogen ions*. The greater the concentration, the more rapid will be the corrosive action. Hence, if any substance forming hydrogen such as carbonic acid or bicarbonate, or sulphur dioxide or any acid-forming compound be present, corrosion is accelerated. On the other hand, if an alkaline material such as soda ash or caustic soda be present, the number of hydrogen ions is decreased and corrosion is retarded. If enough hydroxyl (the active ion of an alkaline compound) be present, practically all of the hydrogen will disappear and corrosion will entirely cease.

In the paper on boiler corrosion already cited, the author has simply added another example to the many already existent, which proves that carbonate of soda in sufficient amount will prevent corrosion in the manner just stated. His suggestion that the engineer readily examine the water in his boiler by withdrawing a sample and titrating it with standard acid is a novel one, and highly to be recommended. Full directions for doing this are given in his paper.

Third, the *ease with which the hydrogen ion reaches the iron*. For example, the wonderful resistance of sheet steel containing small quantities of copper to corrosion when used as roofing is unquestionably due to the adherent nature of the film of oxide produced when corrosion starts. This film, as in the case of the aluminium oxide coat on metallic aluminium, effectually insulates the metal and practically prevents further corrosion.

Fourth, the *osmotic pressure of the iron ions*. This is so small in any case that it is negligible; in the presence of oxygen it is kept extremely low owing to the formation of insoluble iron hydroxide.

Fifth, the *deposition of the hydrogen and its removal by the depolarizing action of oxygen*. The accelerating action of metals such as platinum, copper, and lead, and materials such as coke and mill scale upon the corrosion of iron are undoubtedly due alone to the aid these bodies offer to the elimination of the hydrogen produced by the corrosion reaction, owing both to the low overvoltage of hydrogen upon these substances and to the high catalytic action of these materials on the hydrogen-oxygen reaction by which the deposited hydrogen film is removed.

While in specific cases the corrosion of iron can be absolutely controlled by first one and then another of these factors influencing it, too little attention is generally paid to the last one. The retarding action of the hydrogen film which is stable in the absence of oxygen and any acid-forming compound is so controlling that from this point of view, oxygen (or air) may be said to be the cause of corrosion. If oxygen be completely removed from boiler feed water, the boilers will not pit nor corrode. If oxygen be separated from the feed of ordinary hot-water-supply lines, the "red water plague" and other corrosion troubles will disappear.

By this removal of the cause of the disease not only are all its ill effects avoided but the necessity of drugging with alkali, removal of the products of corrosion,

and such curative measures, with their attendant evils are eliminated, and in this as in so many other cases experience has proved prevention to be better than a cure. If the electrical and mechanical engineers will only take more closely into their confidence their brother electrochemists, we can together more quickly make available the knowledge on the subject of corrosion already at our command for the elimination of the difficulties which it introduces into commercial practice.

* * *

The above paper by Professor Walker was presented at the joint meeting of the American Institute of Electrical Engineers and the New York Section of the American Electrochemical Society on March 10 and was preceded by a paper by Dr. Burton McCollum and G. H. Ashburn on "The Influence of Frequency of Alternating or Infrequently Reversed Current on Electrolytic Corrosion." An abstract of this paper which was read by Dr. McCollum is herewith given:

Influence of Alternating Current on Electrolytic Corrosion

Dr. Burton McCollum and Mr. G. H. Ashburn in their paper on the "Influence of Frequency of Alternating or Infrequently Reversed Current on Electrolytic Corrosion" describe the results of experiments made to determine the coefficient of corrosion (amount corroded divided by theoretical amount) of iron and lead in soil with varying frequencies, with 60 cycles as the maximum and a two-week period as the minimum. The data were obtained as a part of the general investigation of electrolysis conducted by the Bureau of Standards.

Preliminary experiments made with solutions to determine the effect of circulation of the electrolyte on the reversibility of the chemical action, that is, considering that one metal goes into solution when the current is in one direction and is plated when reversed, it was reasoned that rapid circulation of the electrolyte would tend to prevent the replating as mentioned above and consequently a larger coefficient of corrosion would result than in a still electrolyte. These considerations were borne out in the preliminary experiments, and it was also found that the coefficient was higher for the lower frequencies. With iron or lead buried in soil a still electrolyte is encountered so that it would be expected that the corrosive process would be in a large degree reversible even with long periods of time.

A complete series of tests were made both in a jar indoors, and outside in the soil. On account of weather conditions and insulation difficulties it was not found practical to run a complete set of tests outdoors. Tests were made indoors with iron electrodes in normal soil to which sodium carbonate had been added. The same was done with lead electrodes. The outdoor tests were made with iron and lead electrodes but were not so extensive.

The conclusions drawn from the results are as follows:

1. The corrosion of both iron and lead electrodes decreases with increasing frequency of reversal of the current.
2. The corrosion is practically negligible for both metals when the period of the cycle is not greater than about one minute.
3. With iron electrodes a limiting frequency is reached between 15 and 60 cycles per second, beyond which no appreciable corrosion occurs. No such limit was reached in the lead tests, although it may exist at a higher frequency than 60 cycles.
4. With periodically reversed currents, the addition

of sodium carbonate to the soil reduces the loss in the case of iron and increases it in the case of lead.

5. The coefficient of corrosion of lead, under the soil conditions described in the report, when subjected to the action of direct current was found to be only about 25 per cent of the theoretical value.

6. The corrosion of lead reaches practically the maximum value with a frequency of reversal lying between one day and one week.

7. The corrosion of iron does not reach a maximum value until the period of the cycle is considerably in excess of two weeks.

8. The most important conclusion to be drawn from these investigations is that in the so-called neutral zone of street railway networks where the pipes continually reverse in polarity, the damage is much less than would be expected from a consideration of the arithmetical average of the current discharged from the pipes into the earth. Where pipes are alternately positive and negative with periods not exceeding 10 or 15 minutes, the algebraic sum of the current discharged is more nearly a correct index to the total damage that will result than any other figure that can readily be obtained.

9. The reduction in corrosion due to periodically reversed currents appears to be due to the fact that the corrosive process is in a large degree reversible; so that the metal corroded during the half cycle when current is being discharged is in large measure redeposited during the succeeding half cycle when the current flows toward the metal. This redeposited metal may not be of much value mechanically, but it serves as an anode surface during the next succeeding half cycle, and thus protects the uncorroded metal beneath.

10. The extent to which the corrosive process is reversible depends upon the freedom with which the electrolyte circulates, and particularly, on the freedom of access of such substances as oxygen or carbon dioxide, which may result in secondary reactions giving rise to insoluble precipitates of the corroded metal. It is largely for this reason that the corrosion becomes greater with a longer period of the cycle since the longer the period the greater will be the effect of these secondary reactions.

Discussion on Corrosion

This paper elicited an extended discussion in which Messrs. Philip Torchio, Alexander Maxwell, Albert F. Ganz, J. L. R. Hayden, S. M. Kintner, Carl Hering, Asa T. Way, C. B. Martin, Thomas M. Roberts, L. W. Chubb and Thomas Spooner participated.

The discussion of Professor Walker's paper was opened by Professor W. K. Lewis, who had presented the paper in the absence of the author. He showed samples of iron on which by the well-known Cushman-Walker method of indicators the anodic and cathodic regions were clearly and very prettily indicated by different colors. He also mentioned that zinc protects iron from corrosion because it is electropositive to iron; but that aluminium does not protect iron, although one would expect so for exactly the same reason; the reason why aluminium is ineffective for protection is the surface layer of aluminium oxide, which always forms on aluminium surfaces and insulates the aluminium from the solution.

Dr. A. L. Cushman first gave historical notes on the discovery of the indicator method by which the electrolytic nature of corrosion is made visible to the eye. He then referred to the alleged non-corrosive properties of steel containing a small amount of copper. "This is the easiest specification that has ever been offered to the engineering profession. I can go and change a batch of steel into coppered steel by throwing a couple

of handfuls of pennies into the door of the open-hearth furnace. It is a penny-in-the-slot proposition." But Dr. Cushman does not believe in it.

Dr. Cushman then made the first announcement of an extended series of tests which he has carried out on a large scale. Three years ago, in March, 1913, he put out over 300 full-sized 26-gage sheets of every possible analysis of sheet metal that he could obtain for the test. Some were put out in a Western mill town in the midst of smokestacks and chimneys and the clearer air of Washington. He was most careful to see that they were gaged properly and that they were all the same gage; they were not only measured with the micrometer to the best possible extent of gaging full-sized sheets by such a method, but they were weighed individually to see that no great variations of thickness occurred, because this is a matter of prime importance for comparative corrosion tests. These full-sized sheets, which have been out for three winters, are now in his laboratories in Washington, but Dr. Cushman had cut out small samples from them and had brought them along to the meeting.

Out of the 300 sheets which had gone through the exposure tests for three winters, eight had failed, and each one of them is very low in copper. But it would be wrong to conclude that they rusted because they contained no copper. The chief result of Dr. Cushman's tests is that the factor which primarily controls corrosion is the presence of gases in the metal.

Gases (oxygen, hydrogen, nitrogen, carbon monoxide, and to a lesser degree carbon dioxide) may be present in steel in three forms, as the atmosphere in a blow hole, or in the state of a solid solution, or in form of an oxide or hydride or nitride or carbon compound.

In the case of the eight sheets which failed out of the 300, the amount of nitrogen alone in them is five times larger than it ought to be by analysis. The nitrogen in the eight samples was 0.014, 0.015, 0.022, 0.017, 0.019, 0.019, 0.011, 0.016; the carbon monoxide 0.011, 0.016, 0.012, 0.014, 0.015, 0.021, 0.013, 0.016 respectively. "Such stuff as that is bound to rust. It is not a question of whether there is copper in it or not."

Dr. Cushman mentioned the case of a particular pipe which failed while the neighboring pipes were getting along very well. That pipe had nitrogen 0.041, while the other pipes had nitrogen 0.004.

Dr. Cushman said he had such a mass of material to back up his theory that it was a question to him how to get it all out and "present it for publication in such manner and in such way as not to do any injustice to colleagues who do not agree with me. I have arrived at that time in life when I no longer cease to respect a man because he believes something I know is not so."

After discussing briefly the problem of detecting gases in steel sheets and the acid test for liability to corrosion, which was once so much favored by some, but less heard of at present, Dr. Cushman concluded that when the whole discussion of the subject will be over "there will be no engineer who is going to believe in the solid specification any more. What he is going to believe in is the properly made, properly gasified metal. Whether he wants extreme purity or not is another question which he will decide for himself as far as the metallic impurities are concerned. But what he is going to insist on, and what he will find ways of determining for his specification, is the gas content of the metals, particularly when he is spending thousands and thousands of dollars of other people's money in buying these metals."

Mr. Maximilian Toch in speaking of a research which he carried out ten years ago on the corrosion of structures embedded in concrete, said he reached the conclusion that the cathode steel never rusted and the

anode steel always rusted when given sufficient freedom, that is, when the pressure of the concrete was insufficient to prevent the reaction; but neither of the two rusted when coated with an alkali-proof insulating paint.

When Mr. Toch investigated the steel and metal of the battleship Maine when the hull was finally uncovered in 1912, evidences of electrolytic corrosion were manifest, and one particular picture of a bronze binnacle stand that was adjacent to a steel ventilator shaft showed that these two had coupled, the bronze being the cathode and the steel shaft the anode, with the result that the ventilator steel shaft was entirely eaten away and the bronze binnacle stand left in perfect condition. On the other hand, we know that cast iron or iron having a coating of silicide of iron is proof against corrosion, for the very pump that was used for emptying the hull of the battleship was the pump which had been subjected to salt water in the hold of that ship for thirteen years, and when it was taken out only a few connecting rods had to be replaced, the balance of the pump being in excellent condition.

Mr. Toch finally pointed out that iron and steel rusts progressively, but zinc and lead do not. In Belgium roofs are protected with zinc plates, which turn white by reason of the fact that a very fine film of hydrated oxide of zinc is formed, and once this coating is formed no further corrosion takes place. "I am working on this very interesting problem now because iron or steel rusts progressively, which has led me to the conclusion that there may be anodic or cathodic forms of rust," and one form may continue to rust and the other form become immunized.

Mr. Frank N. Speller, in a communicated discussion on the corrosion of water pipes, pointed out that corrosion inside a pipe was quite different from the corrosion of the outside of the pipe in contact with the soil. The degree of aeration of the water is the controlling factor in hot-water supply lines, so that it is of first importance in designing systems where iron pipe is used to provide for the removal of as much of the free oxygen and carbonic acid as possible.

Based on this principle, Mr. Speller has designed and constructed two plants in Pittsburgh for removing these gases from hot water by allowing the water to pass through thin sheets of black iron spaced about one-fourth of an inch from each other, presenting about 100 sq. ft. of surface per cubic foot of space. The corrosive gases are entirely eliminated by a few minutes' contact with these plates at a temperature over 160 deg. Fahr., and are removed at a slower rate at a lower temperature.

Mr. James Aston, in closing the discussion, emphasized the great effect which rust already formed has on the continuation of corrosion.

First—Rust has an effect on the electrode relations at least equal to that of factors recognized as most serious. The potentials are no less than those of iron-carbon, or iron-copper couples, and in this respect the effect of rust is much greater than that of mill scale or cold rolling.

Second—The rust, wet rust at any rate, does not act as an electrode, but rather as a diaphragm which allows penetration of the moisture and prevents or slows down oxygen access to the coated iron surface. The covered iron is the anode and goes into solution, while the iron to which there is more free oxygen access is the cathode and is protected. This is contrary to general understanding.

Third—Rust plays a dual rôle. Fresh wet rust always creates a condition anodic to bare iron, while dried rust is equally cathodic, with a tendency toward re-

versal of polarity on thorough soaking with water. The reversal period varies greatly, from a minute or less to hours or days, depending upon the characteristics of the rust.

That rust is an accelerator of further rusting is a foregone conclusion from the preceding argument. The reversal on drying out serves only to spread the rust, while non-reversal tends to concentrate the effect in localized zones and causes pitting.

It is in the latter effect that the influence of rust is probably of greatest weight, particularly in water-service pipe lines, where the rust has no opportunity to dry out. It appears likely that much of the spread of rust and pitting observed is due to the influence of the rust itself, rather than to inclusions in iron which may soon be covered and obscured.

The Technical Production of Hydrogen and Its Industrial Application

BY HARRY L. BARNITZ, PH.G.

Prior to the year 1907 little importance was given to the technical production of hydrogen gas. Since then, however, the application of hydrogen gas has been continuously and rapidly extended. With the development of the dirigible airship in Germany, it was imperative that hydrogen be cheap and easily obtainable in large quantities. Accordingly the development of the airship may be considered the chief stimulus in the technical production of hydrogen. Germany, France and England have been the principal countries to first utilize the gas commercially. To Germany credit must be given for being the first, not only in developing its technical production, but also in extending its application. In the United States, hydrogen is continually increasing in importance in the industries, but prior to 1913 only little was used.

For the autogenous welding of steel, cast-iron, wrought iron, copper and aluminium and its alloys, hydrogen in combination with oxygen is finding continued increasing application. Hydrogen here presents the great advantages of wide applicability, cleanliness, and cheapness. Another use which is constantly extending is in the cutting of wrought iron and steel. The oxy-hydrogen flame will cut metal up to 24 in. in thickness. In the cutting process considerable excess of oxygen is required, whereas in the welding process a reducing gas mixture is used. The cuts are cleaner than those of a saw, and even in thick metal are only $\frac{1}{8}$ of an inch in width. The rapid extension of the cutting practice by the oxy-hydrogen process is due to its convenience, simplicity and cheapness. The oxy-hydrogen flame is also used for melting quartz and platinum in lead burning, in the manufacture of synthetic jewels such as ruby and sapphire, and in many other technical processes.

In the manufacture of electric lamp filaments hydrogen finds further employment. Large quantities are used in the reduction of tungstic acid and in the sintering and fusing of the tungsten metal powder into rods.

Hydrogen produced by the silicon, aluminum and other similar processes costs from \$5.20 to \$6.85 per 1000 cu. ft. These processes have been displaced by practically three patented processes known as the contact-process (iron process), Rinker-Wolther process (oil process), and the Linde-Frank-Caro process (water gas process). The cost per 1000 cu. ft. varies from 54 to 61c. in these three processes. These figures are given on the basis of prices ruling in Germany. In plants of similar construction in the United States the cost of production is between 85c. to \$1 per 1000 cu. ft. In the United States only four plants of the newer type have so far been installed: two plants of 3530 cu. ft. per hour,

one of 10,600 cu. ft. per hour, and one of 8000 cu. ft. per hour. Over fifty electrolytic hydrogen plants have been installed in the United States in the past five years, and the total amount of hydrogen now being generated by all processes per year in the United States is over 300,000,000 cu. ft.

The number of mechanical and chemical plants of the improved type erected in Europe up to the summer of 1914 (that is, up to the time when the war broke out) was 23, of a total capacity of 3530 to 10,600 cu. ft. per hour. Three of these installations produce 200 to 880 cu. ft. per hour. All of these plants in Germany, Russia, Austria, Sweden, Holland, Italy and England were installed by Germans. Other large installations were negotiated for, but the writer is unable to ascertain facts regarding them due to conditions at present in Europe. No doubt Germany has increased its hydrogen-producing plants; likewise England, France and the other countries. New installations were undoubtedly required for the increased number of airships and observation balloons which have been built during the war.

Modern Processes of the Technical Production of Hydrogen

LINDE-FRANK-CARO PROCESS—A PHYSICAL LIQUEFACTION WATER GAS PROCESS.

In this process water gas, consisting almost solely of carbonic oxide, CO, and hydrogen, is cooled and compressed until the carbonic oxide is liquefied, while the hydrogen still remains gaseous and can be drawn off. The apparatus consists essentially of a water gas plant and a plant for the separation of the hydrogen from the carbonic oxide gas.

The water gas is produced in the usual way by passing steam through incandescent coke, whereby the steam is decomposed, its oxygen forming carbonic oxide with the carbon of the coke, while its hydrogen remains free. Water gas, on the average, consists of hydrogen 50 per cent, carbonic oxide 40 per cent, carbonic acid 4 per cent, nitrogen 5.5 per cent, methane 0.5 per cent, with smaller proportions of oxygen, sulphuretted hydrogen, and carbon bisulphide.

The hydrogen is separated from the rest of the gases by compression and cooling. The boiling point of hydrogen, —253 deg. C., is much lower than that of the other constituents, that of carbonic oxide being —192 deg. C., and that of nitrogen —196 deg. C. On cooling compressed water gas to the temperature of liquid air, —193 deg. C. all of the constituents except the hydrogen are liquified. The hydrogen thus easily separated in the gaseous state is of a high degree of purity.

Before this separation by cooling is attempted the water gas undergoes preliminary treatment for the extraction of carbonic acid, which, if not removed, would block the narrow tubes of the rectifying apparatus. The removal of the carbonic acid gas is affected for the most part by compressing the water gas, in contact with cold water, up to a pressure of about 12 atmospheres. At high pressures water absorbs carbonic acid more easily than at atmospheric pressure, and hence the quantity of water required for absorption is reduced. The small residue of carbonic acid still remaining in the water gas is extracted by passing the latter through caustic soda.

This method of compressing water gas and cooling it by liquid air produces hydrogen 97 to 98 per cent pure. The residue consists of about 1 per cent each of carbonic oxide and nitrogen. Sulphur, dust and moisture are absent from the gas. The hydrogen leaves the apparatus under a pressure of 25 atmospheres, which is a considerable saving of power when cylinders have to be filled with gas under pressure. Two to four men can

operate a plant, depending on its size. The plant is kept in continuous operation for about a week; it is then advisable to shut down the hydrogen separating section in order that all the worn tubes may be cleaned. A second unit of this section of the plant is kept in reserve for use while the first unit is being cleaned. To bring the entire plant into operation requires twenty to twenty-four hours.

THE CONTACT PROCESS—KNOWN AS THE LANE OR IRON AND STEAM PROCESS.

This process depends upon the well-known property possessed by incandescent iron of decomposing steam which is passed over it. The oxygen of the steam combines with the iron and the hydrogen is liberated. In the practical working of the process reduced iron ore is used which has the advantage over ordinary metallic iron of having a larger active surface and caking or fluxing less readily when heated.

The manufacture of hydrogen by this process proceeds in alternating period, in one of which oxidized iron is converted by a cheap reducing gas to spongy iron, and in the other period steam is passed over the spongy iron with liberation of hydrogen. The cycle of operations proceeds continuously.

The essentials for the process are, therefore, iron ore, reducing gas and steam. Water gas is used as the reducing gas, and thus the plant required consists of a water gas installation and a special hydrogen apparatus.

The decomposition of the steam by the incandescent iron is effected in vertical iron retorts set in furnaces heated by producer gas. The retorts are charged with iron ore through the upper lids. Above the retorts are valves for regulating the passage through the retorts of steam and of reducing gas alternately and for taking off the hydrogen and the spent reducing gases. The latter, consisting chiefly of carbonic acid and steam, are either discharged into the open, through a shaft or are passed in to the retort furnaces, where any unconsumed constituents are utilized in heating the retorts.

The hydrogen gas thus produced passes from the retorts to the purifying plant. The first section of the latter is a condenser packed with coke sprinkled with water. From this condenser the hydrogen goes into two purifying vessels, worked in series, for the extraction of sulphur and carbonic acid. The gas then passes to a gasholder, from which it can be taken either for immediate use or to a compressing station, where it is filled into cylinders. The hydrogen finally obtained by this process has a specific gravity of 0.090–0.092; its purity is 97 to 98 per cent, the residue consisting of nitrogen, with 0.2 to 0.3 per cent carbonic oxide; furthermore, since the gas was cooled by contact with water it is saturated with water vapor.

A plant for producing 3500 cu. ft. per hour requires four workmen for each shift. Skilled labor is not essential. The iron ore which is used in the process can be kept in the retorts in uninterrupted operation for about two or three months. For efficient service the plant must be worked continuously, since it requires fourteen to twenty-four hours to start up from the cold.

THE RIKER-WOLTER PROCESS—A CHEMICAL PROCESS FOR THE DECARBURATION OF OIL.

This process is the result of a research which originally aimed at the production of an illuminating gas, but failing in this a highly efficient hydrogen-producing process which is now being used to a great extent by the iron-steam and the contact process. It is this process which is now being used to a great extent by Germany and Russia in their aeronautical work owing

to the portability of the apparatus. Complete installations are set up on railway cars and carried from point to point as required. The plant takes up but little space, and is more easily supervised than the two other processes described above.

The process is one in which gas oil is used which is heated to 1200 to 1400 deg. C. and decomposed into its chief constituents, carbon and hydrogen. The plant comprises the special gas-making plant and purifiers. The gas-making plant consists of two producers which are charged with coke. There is a gas connection from the lower part of the first to the upper part of the second producer; near the furnace and clinkering doors of the producers are air inlets. These air inlets are fitted with valves having interlocking gears to prevent accidents arising from careless manipulation. The air required to raise the heats in the producers is forced through these inlets by a high-pressure blower.

When the producers have reached the requisite temperature, the blower is stopped and the blast valves closed. Oil is then pumped onto the coke in the first producer, through spraying nozzles which atomize it. It is converted into vapor by the hot coke and passes through the bed of hot coke in the second producer. In this way the vapor is converted into a permanent gas, which leaves the bottom of the second producer and enters a hydraulic main. When the air is in turn again blown in at the base of the producers in order to raise their temperature, the carbonaceous residue left by the oil on the coke is burnt and contributes towards the heating up of the producers. It requires one to one and a half minutes' blast to raise the producers to the proper temperature again. Thereupon oil is again introduced into the first producer.

The oil is preheated in order to render it sufficiently thin and mobile to pass through the spraying nozzle. For preheating the oil the exhaust steam from the turbine or engine used for driving the blower is utilized. Solid impurities are removed from the oil by pumping it from the storage tank through a filtering chamber.

The gas issuing from the second producer passes through a water seal in the hydraulic main, and there deposits the greater part of the sooty matter which is carried over mechanically. Clean water flows continuously into the hydraulic main, and the sooty water flows off and runs into a settling pit, having partitions which force the water to take a long and tortuous course in order to ensure the deposition of the solid matter.

The last two chambers of the settling pit are packed with coke, which acts as a filter and retains the last traces of impurities, so that the water may be run thence direct into any sewer or river. Soot is the only by-product of this process; the oil contains 80-85 per cent of carbon, of which the greater part is liberated; only a small proportion of carbon is found in the form of hydrocarbons and carbonic oxide in the crude hydrogen gas. Most of the liberated carbon is retained by the coke in the producers, and is later burnt by the air blast. A small proportion goes forward as soot in the gas, and is deposited in the hydraulic main and washer. The soot which collects in the settling pit when dried can be burnt under the boiler. The gas passes from the hydraulic main into a washer, where sprays of water remove the last traces of soot.

On leaving the washer the gas contains 6 to 8 per cent of carbonic oxide and sulphuretted hydrogen. The latter is removed in a purifier charged with bog iron ore. The carbonic oxide is extracted by hot soda-lime in the following manner: The gas passes from the iron oxide purifier into thin-walled retorts, set in a furnace which keeps the soda-lime with which the retorts are charged at a temperature of about 300 deg. C. At this

temperature the soda-lime absorbs the carbonic oxide from the gas. The gas thus purified is cooled by passage through an atmospheric condenser and is then stored in a gasholder. The purity of the gas is from 97 to 98 per cent, the residue being nitrogen. The specific gravity is 0.087 to 0.090.

The operation of the plant is not difficult, and requires only moderate supervision. The producers can be heated up for use in one to two hours, and can be operated continuously for a few hours at a time or for days, weeks or even months.

An installation of this type may be either stationary or portable. The layout of a portable installation of this process, as now used by the governments of Germany and Russia, is as follows: The producers, with oil tank, oil pump, pre-heater and hydraulic main, are installed on one railway truck, and the purifying plant, including the washer and the final condenser, is arranged on a second truck. A gas holder constructed of balloon-fabric is carried on a third truck. The gas then passes from this holder to a compressor, placed on a fourth truck, by which it is compressed into steel cylinders.

PRODUCTION OF HYDROGEN BY ELECTROLYSIS.

In this process water is decomposed into its constituent elements, oxygen and hydrogen, by the aid of the electric current. One of the first commercial plants of this type to be erected in the United States was at Waverly, Newark, N. J., in 1911. The electrolytic generators, or cells, are of two types; the unit type is composed of an outer tank, which serves as the negative electrode, and a perforated inner tank made of special composition iron which serves as the positive electrode. The two electrodes are separated by means of a specially prepared asbestos diaphragm which divides the apparatus into two compartments. On top of the cover are the current terminals, two sight feed indicators and pressure equalizers, also a cup through which water is introduced into the cell from time to time.

As soon as the electric current is applied oxygen and hydrogen are seen to bubble through the indicators. The electrolyte is an aqueous solution of caustic potash or soda, which serves to make the water a good electrical conductor. In each cell about 1 gal. of water is decomposed per 24-hr. day, producing 76.8 cu. ft. of oxygen and 153.6 cu. ft. of hydrogen. The hydrogen is liberated on the walls of the outer tank (negative electrode), while the oxygen forms on the walls of the inner tank (positive electrode). The oxygen is carried up through suitable means to the oxygen equalizer, where it bubbles through water and passes on to the oxygen off-take pipe; the hydrogen similarly passes through the hydrogen equalizer and thence to the hydrogen off-take pipe. Each cell produces per kilowatt hour, 8 cu. ft. of hydrogen and 4 cu. ft. of oxygen. The current required per cell is 400 amp. at 2 volts. The purity of the electrolytic hydrogen is 99.8 per cent and the oxygen 99.6 per cent.

The cost of hydrogen by this process, disregarding the value of the evolved oxygen, is about $\frac{1}{8}$ of a cent per cubic foot at a current cost of 1c. per kw.-hr. at the generator. For small or moderate size plants where low cost current is available the electrolytic process is preferable to any other for the production of hydrogen.

The attractive features of this process are: (1) the simplicity of operation; (2) the little attention required (not exceeding the cost of a few hours of one man's time per day); (3) cheap raw material (requires only 1 gal. of water to be added to each cell per day). The plant can be operated continuously for years without cleaning or overhauling; the process is clean and

safe, and the cell produces gas as soon as the current is turned on.

Another variation of the unit type generator or cell is the bipolar generator recently placed upon the market.[†] This type of generator is of the filter press type, but is not a modified filter press. While the form of this generator was early introduced in the art the bipolar type only resembles same in form. It is specifically designed for the electrolytic separation of water at the highest efficiency. This type of generator is to be commended where floor space is a consideration, as it is more compact than the unit type cell. The bipolar generator is made in two sizes. The 4 x 11 ft. has a rated daily capacity of 1700 cu. ft. of hydrogen and 850 cu. ft. of oxygen. Size 5 x 15 ft. has a rated 24-hr. capacity of 700 cu. ft. of hydrogen and 3500 cu. ft. of oxygen. The above capacities are based on the use of caustic potash as electrolyte. Purity of the hydrogen is 99.8 per cent and oxygen 99.6 per cent. The generator may be operated twenty-four hours a day and 365 days in the year. The cost of the gases produced is about the same as in the unit type. The bipolar generator is as completely automatic as a high duty generator of this type can be made. Practically the only attention required in operation is in the maintenance of the water supply. Only part of one man's time is necessary.

Hydrogen in the Industries

HYDROGEN EMPLOYMENT IN QUARTZ GLASS.

Quartz glass, which has long been recognized as an important material in the manufacture of various articles employed in the chemical industry, was first produced in 1839 by Prof. Gaudin. Some of his quartz tubes and elastic threads were exhibited at the Paris Exposition in 1878.

In 1889, Boys, who recognized the possibilities of this remarkable substance, also succeeded in making small tubes and other articles.

However, little progress was made in the development of the quartz-glass industry until 1900, when Heraeus and Achenstone succeeded in making clear rock crystal articles large enough for practical purposes. The raw material is washed quartz sand containing 95 per cent silicic acid, which is melted by the oxy-hydrogen flames, and it is now possible to melt and to mold into almost any desired form as much as 50 lb. of quartz at a time.

One of the remarkable properties of the quartz glass produced by this process is its resistance to acids. Even boiling acids, with the exception of hydrofluoric and phosphoric, will not readily affect it. Quartz has the advantage of having a very low co-efficient of expansion, being about 1.17 that of the best glass suitable for chemical utensils and apparatus. The manufacture of quartz glass in the United States is only of very recent date.

HYDROGEN IN BALLOONS AND DIRIGIBLE AIRSHIPS.*

Hydrogen, on account of its very low density, has the greatest lifting power of all gases, and is therefore used for filling balloons. The amount which a balloon will carry up, i.e. "its ascensional power," is the difference between the weight of the balloon itself with its contained hydrogen, and that of an equal volume of air. A liter of hydrogen gas has an ascensional force of 1.2 grams. The specific gravity of 98 per cent hydrogen is 0.087, which corresponds to a lifting power of 73.5 lb. per 1000 cu. ft. Pure hydrogen has a specific

gravity of 0.07; which corresponds to a lifting power of 75 lb. per 1000 cu. ft.

Hydrogen for balloon purposes must be free from impurities that would injure the fabric, and should be dry. It is not necessary that the hydrogen be under pressure for inflating a balloon. It will readily inflate at atmospheric pressure.

MELTING OF PLATINUM.

In the melting of platinum the oxy-hydrogen burner is used exclusively. The temperature of the oxy-hydrogen is about 2100 deg. C., whereas the melting point of platinum is 1755 deg. C. The great advantage of this flame is that it contains no elements injurious to the platinum such as carbon. Illuminating gas, which was formerly used instead of hydrogen, was detrimental to platinum. The operation is carried out by passing oxygen and hydrogen at high pressure through an especially constructed oxy-hydrogen torch. The author devised a torch for this work several years ago, and it is practically the only platinum melting torch (oxy-hydrogen) used to-day in the United States by platinum smelters. The melting is best accomplished in a lime crucible. Oxygen and hydrogen at a pressure of 1800 lb. per square inch in cylinders containing 100 and 200 cu. ft. with reducing valves and regulators are used.

PRODUCTION OF THE SYNTHETIC RUBY AND SAPPHIRE.

Practically all of the beautiful minerals of the corundum family are now being produced synthetically. The ruby and sapphire are the more important.

Alumina being the base of those precious stones, it remains only for the chemist to add the proper oxide to obtain the required colors and to fuse them together in the oxy-hydrogen flame. The ruby, for example, contains 98 per cent of pure alumina and about 2 per cent of chromic oxide.

The materials used are of the purest. It is absolutely essential that the material be pure, as otherwise the product obtained will be faulty and the color will be poor.

At a temperature of 1000 deg. C. the material is calcined in a large oven and removed and reduced to a fine powder. The fine powder is then placed in the magazine of the oxy-hydrogen burner and forced down on a receiving base below the flame. The work at this stage is very delicate and requires most careful attention. All conditions must be regulated with mathematical precision, the rate of flow of the Al_2O_3 powder, the rate and pressure of the gases and the quality of the flame (1900 deg. C.). With conditions properly adjusted the stone at first appears as a little stalk not larger than a pin head, which gradually grows in the fire. This stalk, as it grows taller, is broadened out by the manipulation of the torch by a skilled operator so as to form a small cone with the point down. The desired size obtained, the operator shuts off the gases and allows the jewel to cool. It is then broken from the base and is ready for cutting.

Electrolytic oxygen and hydrogen are used exclusively in this industry on account of the exceedingly high degree of purity of the electrolytic gases.

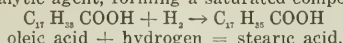
HYDROGENATION OF OILS.

In connection with the fat industry a very extensive use for hydrogen has developed. By the introduction of hydrogen into fatty bodies and oils of low melting point these are converted into hard fats of higher melting point. In other words, oils which are composed of unsaturated acids, such as oleic acid and their esters,

[†]See MET. & CHEM. ENG'G, Vol. 14, p. 108.

*Cf. Ardery, MET. & CHEM. ENG'G, Vol. 14, p. 333.

will combine with hydrogen in the presence of a suitable catalytic agent, forming a saturated compound:



The hard fats have a greater market value for the manufacturer of soap, candles and oleomargarine. Fish oils, etc., lose their disagreeable odor in the hardening process. The application of hydrogen in the fat industry has brought about a great advancement. The process worked out on the following lines is known as hydrogenation.

The addition of the hydrogen to the unsaturated hydrocarbon of the soft fats is accomplished by exposing the latter to hydrogen under pressure at high temperature in the presence of a contact agent such as a mixture of finely divided clay with metallic nickel, copper or iron. This mixture is sprayed into a container made of boiler plate under a pressure of 4 or more atmospheres, the pressure varying according to the method of working and the catalytic agent employed. Into the container from the opposite end is introduced a current of hydrogen, which at a temperature of about 150 deg. C. readily combines with the oil or reduces the fatty acids. The hydrogen is added in excess in order to facilitate the conversion, but the surplus hydrogen, after being freed from oil particles, is returned to the storage tank.

The consumption of hydrogen varies according to the nature of the raw material and the hardness of the product. It is usually from 2870 to 4300 cu. ft. per ton. The fatty product run-off from the pressure vessel is an emulsion of the fat with the contact substance. The latter, after separation by centrifuging, is used over again.

The contact substance, according to the patent of Leprince and Siececke (Dr. Norman) is finely divided nickel or copper; according to Fokin, it is platinum, and according to Paal, palladium. With the last two conversion is effected at ordinary or relatively low temperature and at an exceedingly low pressure. Wherever these two rare metals in suitable form are used, many improvements in the process have lately been introduced. It is absolutely necessary to use hydrogen of a high degree of purity, since slight impurities in the gas will render the contact substance inactive. In the hydrogenation of cotton seed oil, 1 per cent of hydrogen by weight converts it into a fatty body of the consistency of lard. The product obtained is edible.

THE SYNTHETIC PRODUCTION OF AMMONIA.

The discovery of the synthetic production of ammonia by Professor Haber of Karlsruhe a few years ago promises a very extensive use for hydrogen. It is of immense importance because it forms the basis of the well-known fertilizer, sulphate ammonia. When hydrogen and nitrogen are heated to 200 deg. C. in their combining proportions, under high pressure and in the presence of uranium as a contact substance, they unite to form ammonia. About 6 per cent of ammonia is produced, and by removing this a further conversion is effected. The yield can undoubtedly be greatly increased and the process accelerated by the selection of a possibly more suitable contact substance and the application of possibly more appropriate temperature and pressure.

A Proposed Quick Analytical Method for Determining the Zinc in Retort Residues or Electric Zinc Furnace Slags

BY WOOLSEY MCA. JOHNSON

The method indicated by the above title was devised by me in 1904 when running the No. 2 Plant of the

Lanyon Zinc Co., at Iola, Kansas. It was tried out in a preliminary way at the La Harpe electric furnace laboratory but never perfected. It is thought that it has been perfected on the drawing-board and it should work all right, although changes will be found necessary when apparatus and method are tried.

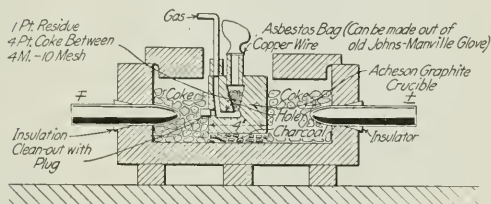
Briefly described the apparatus is similar to the 20-kw. test electric crucible furnace working at 15 to 45 volts, such as I developed in 1903, made of No. 8 sheet steel with riveted 2-in. angle bars on corners and 3-in. electrode. It can be made of one course of magnesia or of one course of magnesia and one course of firebrick or Armstrong nonpareil insulating brick.

In it is placed a machined 4-in. Acheson graphite electrode with a centered conical hole at the bottom of which enters a 1/2-in. hole. Through the latter a stream of gas flows upward.

The gas is led in by a vertical hole, connecting with an iron pipe to gas supply.

In the center of the tester is placed a mixture of 1 part residues, 4 parts coke, the latter sized between 10-mesh and 4-mesh.

Into the working space of the crucible is screwed an



APPARATUS FOR DETERMINING ZINC

Acheson graphite plug on the top of which is a hood of asbestos cloth. The purpose of this last-mentioned is to catch the zinc dust.

When the apparatus is set up and a weighed amount of residue in the tester, the temperature is quickly raised to 1600 deg. C. and a good flow of gas maintained. At this temperature, the zinc is all reduced because reductivity both in gaseous and solid phase is tremendous. The fume is caught in the bag as high metallic blue-powder with nearly all the lead.

It only remains to cool the bag down carefully and dissolve the zinc in acid so dilute that asbestos is not affected. The solution after a sulphate is added is then ready for the usual titration, as it is now pure ZnSO₄. As an alternative, the zinc vapor can be caught on glass-wool in a suitable small dust-collector, which is preferable but not worked out to my satisfaction in my own mind.

The zinc may also be determined by measuring the hydrogen evolved under proper conditions as would occur to the mind of any technical chemist.

In case of electric zinc furnace slag, it must be ground very fine and mixed with a larger amount of coke. My preferred course of treatment would be to take a large amount of the material (10 to 40 grams) to be analyzed, taking a fraction of same for the final determination. There is no reason why the entire determination cannot be made in 15 minutes. It would be much more accurate than the usual method which leaves some zinc undissolved. A battery of crucibles or a 4-in. x 4-in. x 24-in. electrode with a plurality of holes with perforated graphite or "alundum baskets" could be used in the works laboratory.

If power were cheap and plentiful, I have no doubt that it could be developed into a very satisfactory technical method.

Recent Chemical and Metallurgical Patents

Iron and Steel

Agglomerating Fine Ore.—A process and device for agglomerating or sintering flue-dust or fine ore is illustrated in Fig. 1, being the patented invention of PHILIP O. HARDING of Pittsburgh, Pa. The feature of the invention consists in submitting the material to be treated to a progressive combustion, and in providing a flow of air to support combustion in a direction counter to

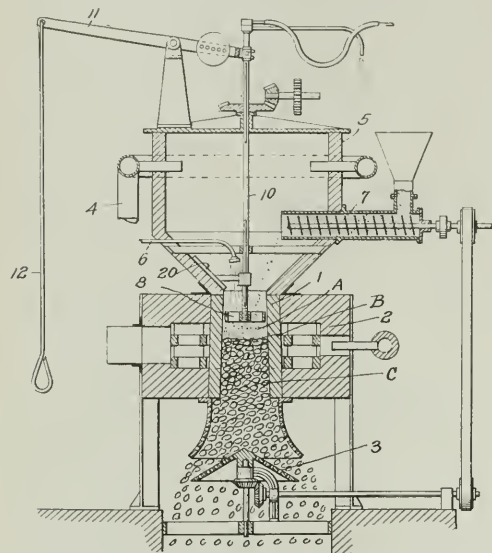


FIG. 1—AGGLOMERATING MACHINE

the flow of material. This counter-current flow of air serves to sweep any unsintered particles back into the zone of combustion for further treatment. The sintering chamber 1 is of tubular form, surrounded by an annular reverberatory chamber 2 from which the supply of heat comes. Air for the support of combustion is drawn upward through the body of material into an exhausting chamber 5 from which the air is drawn through a pipe 4. The material to be sintered is introduced by screw 7 and is distributed and leveled by the spreader and pusher 8. Discharge is effected by the revolving cone 3 which to a certain extent disintegrates the sinter cake, exposing any friable or untreated material to the current of air which carries it back into the fire zone. (1,166,903-4, Jan. 4, 1916.)

Recovering Flue-Dust.—A method of preparing flue-dust for further reduction in the blast-furnace is disclosed in a patent granted to SAMUEL W. OSGOOD, Chicago, Ill. He proposes to mix the flue-dust with water and perhaps a suitable binder, such as lime or coal-tar, and form pellets of desired size. In order to reduce the iron oxide contained in the flue-dust to metallic iron, he utilizes the heat and reducing gases of the blast-furnace slag by introducing the pellets into the molten slag as it leaves the furnace. By subsequently granulating the slag, the iron pellets can be recovered by screening, gravity separation or magnetic separation. (1,166,927, Jan. 4, 1916.)

Washing Blast-Furnace Gases.—The application of the counter-current principle to the washing of furnace gas, and the conduct of the operation in three

stages form the basis of the patented process of HERMANN A. BRASSERT of Chicago, Ill. The first stage consists in thoroughly wetting every part of the gas, using the counter-current principle so that the hot, dirty gas encounters first the warm, dust-laden discharge water; the washed gas encountering the cold water entering where the gas leaves. This removes the greater portion of the solids; and in the second stage the finely divided matter is removed in similar manner by subdividing the streams of gas and water more finely and introducing baffles. In these two stages of washing every drop of water is used over and over, being retarded and arrested as often as possible until it has taken up the maximum charge of dust. The third stage consists in drying the gas, and in this stage it is desirable to reverse the conditions in the first two stages, viz., by removing water as quickly as possible from the path of the gas.

Apparatus for the first two stages consists of a vertical cylindrical tower. For the first stage the tower contains a series of trays. The second stage is arranged immediately above these trays and consists of wooden slats arranged at different angles to the flow of gas so that the direction of flow is changed between each set of slats. For the third stage a cylindrical casing is provided, into which the gas enters in a horizontal direction

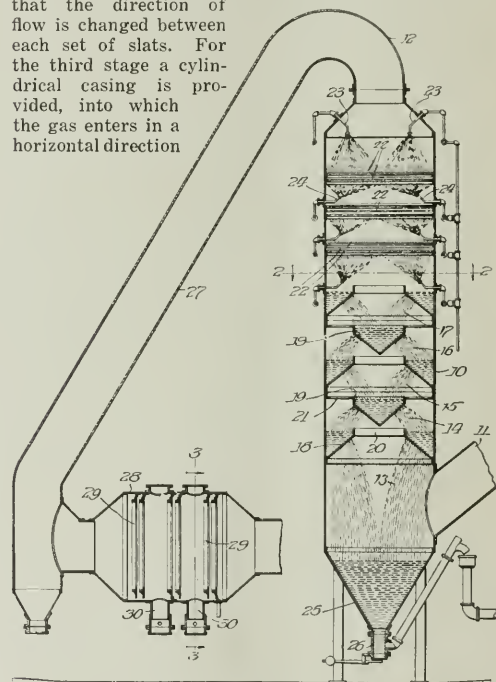


FIG. 2—GAS WASHER

and flows through sets of vertical wooden baffles, on which the water entrained in the gas collects and trickles downward out of the path of the gas. This water is finally collected in receptacles at the bottom of the drying chamber. The construction of the gas washer is shown in Fig. 2. (1,169,764-5-6, Feb. 1, 1916.)

Gold and Silver

Cyaniding Under Pressure.—In apparatus for cyaniding, patented by MR. BRUNO KOERING of Detroit, Mich., all of the processes of agitation, filtering and washing are conducted in a single revoluble filter drum.

In case the ore is originally ground in water, the pulp is first dewatered in the drum before cyanide solution is added. After the ground ore and solution are thoroughly mixed in the drum, air or steam is introduced to bring the pressure up to from 15 to 60 lb. per square inch, and the drum is then slowly revolved for two to eight hours, according to requirements. The solution is then displaced through the filter lining and the pulp is washed with barren solution or water, after which it is discharged. The original cyanide solution may be heated, or heat may be supplied from steam introduced under pressure.

Slime Filter.—A type of vacuum filter, in which the operation of filtering takes place in a horizontal frame and the cake is discharged by tipping the filter to an inclined or vertical position, is patented by Mr. CHARLES BUTTERS of Oakland, Cal. The cake is formed by flowing a stream of pulp onto the filtering medium until a cake of desired thickness has been formed. After forming the cake and removing the valuable liquid, a wash solution may be directed over the cake for the purpose of displacing any valuable solution that may remain with the solids. After the cake is washed it is discharged by tilting the horizontal frame to an inclined or vertical position. Any number of filter units can be combined in a suitable frame. An earlier reference to this filter was made in this journal, April, 1914, giving illustrations of the apparatus in various positions. (1,165,068, Dec. 21, 1915.)

Copper

Method of Smelting Finely Divided Ores.—Finely divided ores are not suitable for smelting in the blast-furnace on account of the readiness with which they are carried out by the blast, and they are difficult to smelt in reverberatory furnaces by reason of their tendency to pack and prevent reaction gases from gaining access to the individual particles. In order to obviate these difficulties in smelting finely divided ore, Messrs. JOHN H. KLEPINGER, MILO W. KREJCI and CHARLES R. KUZELL, of the Anaconda company's staff, at Great Falls, Mont., have patented an improved process of smelting such ores. The object is to so handle the ore that each particle will be surrounded, as it enters the furnace chamber, by the heating medium and reaction gases. The process may be either oxidizing or reducing, according to the nature of the ore and the desired result, but in any event the object sought is to envelope each particle of ore with a gaseous film, thereby insuring the smelting of the ore in a minimum of time and in the most economical manner. For this reason provision is made to feed the charge in the form of a spray or cloud.

The process applied to the reduction of oxidized ores is illustrated in plan in Fig. 3, and may be explained with relation to oxidized ores of copper which are reducible by reaction with a reducing agent. Referring to the figure, 1 represents an inclined revoluble smelting cylinder which is a combined combustion, treatment and reduction chamber; 4 is a two-compartment hopper from which the materials, ore and fuel, are fed by

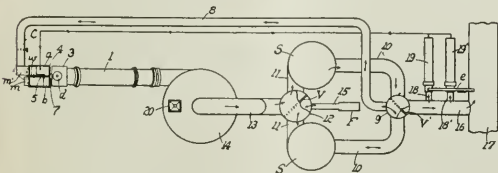


FIG. 3—SMELTING FINELY DIVIDED OXIDE ORES

screws to an air-nozzle beneath and thence into the igniting chamber 3 and upper end of cylinder 1. A settling chamber 14 is provided as a receptacle for the smelted product, from which slag and metal can be withdrawn from tap-holes. The waste hot gases pass from the settling chamber through one of the preheating stoves *S, S'*; and at the same time air is forced through the other by fan *F*. Suitable reversing valves *V* and *V'* permit the alternate heating of one stove by the waste gases while the other is preheating air for the smelting operation. After leaving the stove, the hot waste gases pass on to driers 19 and 19', containing the ore and fuel charge, respectively, and from which the dried charges are conveyed to their hoppers *a* and *b*. Before commencing smelting operations, the combustion and settling chambers and stoves are brought to the proper temperature by burning a certain quantity of powdered fuel, after which ore may be introduced. The reduction of the metallic oxides and the fusion of the resulting metal are accomplished in the chamber 3 and cylinder 1 while the particles are still in suspension, the atmosphere in the apparatus being kept in a highly reducing condition. The products of smelting flow down the cylinder into the settler 14. (1,160,621, Nov. 16, 1915.)

The same principles may be applied to the smelting of finely divided sulphide ores or concentrates, such as result from the flotation process. In this case the re-

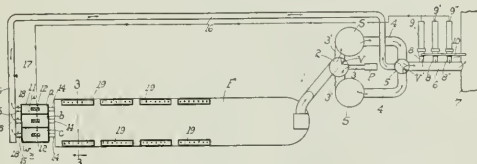


FIG. 4—SMELTING FINELY DIVIDED SULPHIDE ORES

action is oxidizing in character, and the fuel may be derived wholly or partly from the ore itself through the oxidation of such constituents as sulphur, iron, arsenic, etc. In the case of copper ores the product is a matte. This process is illustrated diagrammatically in plan in Fig. 4, in which the heat-regenerating apparatus is shown in connection with a reverberatory furnace. The ore, flux, and fuel when necessary, are dried in driers as above described and delivered to screw-feed hoppers *a, b* and *c*, from which they are blown into the furnace by means of air preheated to a temperature of about 1000 deg. Fahr. in the stoves *S, S'*. The charge being delivered into the furnace in the form of a spray or cloud, each particle of ore is surrounded by the heating and oxidizing medium and is fused or smelted in suspension. Over-oxidation may be corrected by introducing coarse raw ore into the furnace through the side hoppers 19. The process eliminates the preliminary step of roasting that is necessary in the former methods of smelting. (1,164,653, Dec. 21, 1915.)

Ozone

Ozone Generator.—An ozone generator designed to prevent short-circuiting of the apparatus by moisture and to provide a simplified construction and new arrangement of the cooling system is patented by WILLIAM O. FREET of Hackensack, N. J. (assigned to Steynis Ozone Co. of New York). In this generator short-circuiting by moisture is prevented by inclosing the entire apparatus in an air-tight box, and placing a drying element in the box. The drying element contains calcium chloride or some other suitable absorber of moisture. Another feature which prevents short-

circuiting by moisture is the admitting of the air between two concentric electrodes instead of outside the electrodes. A cross-section of the generator is shown in Fig. 5. The outside casing 1 contains two separate ozonizing elements as shown. The inside electrode 8 is made with a spiral groove to provide large discharge space. The outside electrode 19 is a concentric tube inclosing dielectric 12, inside electrode 8, and cooling pipes 9 and 10. The air enters at 14, passes down through ozonizer between inside electrode 8, and dielectric 12, where the discharge takes place and ozone is formed. It then passes out through opening 6 and up

generator. From here the ammonia is conducted back to the compressor.

Following the course of the air it is first compressed in an air compressor. It then passes to the drying and cooling chamber through which the above mentioned ammonia cooling pipes pass. From here the air passes to the ozone generator which may be of any approved type. The type preferred, however, is one in which the air in passing through the generator is subjected to the cooling action of the cooling medium and to electrical discharges successively.

The cooling medium flows in a closed circuit, and by first causing it to pass through the drier and then through the generator, the temperature in the generator will be slightly higher than in the dryer, which insures against moisture being precipitated from the air in the generator which would seriously interfere with the generator. It is also claimed that with this system an even temperature may be maintained in the ozonizer. (1,162,415, Nov. 30, 1915.)

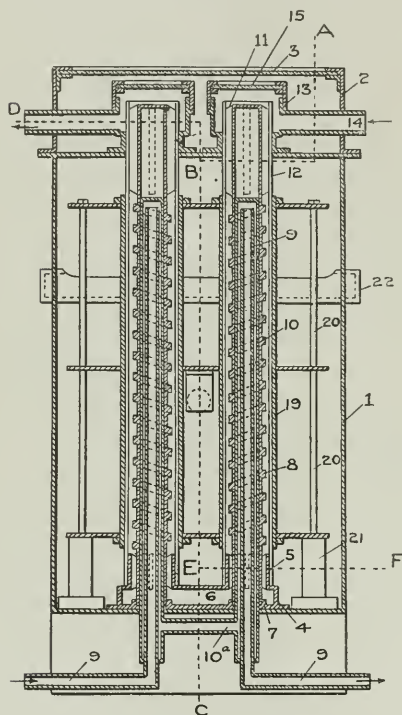


FIG. 5—OZONE GENERATOR

through the other ozonizing element and thence out of the apparatus. The cooling medium, ammonia brine or other suitable substance, passes in through left-hand pipe 9 in the opposite direction to the flow of air so that the hottest air or ozone will come in contact with the cooling fluid first. The cooling fluid passes up through pipe 9 out over its top, down between pipes 9 and 10 into direct contact with the electrode. The cooling fluid passes down and through passage 10a and thence to the right hand ozonizing element. The drying element is shown at 21. (1,157,859, Oct. 26, 1914.)

Process of Producing Ozone.—A process and apparatus for producing ozone is patented by JAN STEYNIS of Bay Shore, N. Y. The operation of the process is as follows: An ammonia compressor delivers compressed ammonia to cooling coils where it is condensed to a liquid. The liquid ammonia is then conducted to a coil of pipe in a chamber used for drying and cooling the air. In this latter coil the ammonia becomes gasified again. From the drying chamber the ammonia gas now goes to the jackets of the cylinders of the ozone generator where it cools the air as it passes through the

Synopsis of Recent Chemical and Metallurgical Literature

Slime Settlement

Determining the Capacity of Slime Settling Tanks.—In an elaborate paper contributed to the *Transactions* of the American Institute of Mining Engineers, H. S. COE and G. H. CLEVENGER present preliminary results of a laboratory method for determining the capacities of slime-settling tanks. The general phenomena of settling were studied by observing the action of thin pulps in glass cylinders, and defining four zones into which the pulp separated during the process of settling. As a result of this study the authors derive the

formula $C = \frac{62.35R}{F - D}$, where 62.35 = weight of 1 cu. ft. of water.

F = ratio of fluid to ore in the pulp tested.

R = rate of settling in feet per hour of a free-settling pulp of consistency F .

D = ratio of fluid to solids in the discharge required.

C = capacity in pounds of solids per square foot per hour, which may be discharged with a consistency of D from a layer of pulp of a consistency of F settling at a rate R .

The results of the investigations are summarized as follows:

1. In thickening pulps which are to be discharged at a consistency such that the discharge is still in the form of free-settling pulp, the depth of the tank used is of no consequence, except in so far as it permits a depth of feed sufficient to avoid surface agitation and allows ample depth of clear liquid to care for fluctuations of the feed and changes in the character of the pulp in the case of continuous thickeners, and sufficient depth to give ample capacity to avoid the necessity of frequent charging and discharging in the case of intermittent thickeners.

2. When thickening pulps to a consistency where it is necessary to expel fluid by compression, sufficient capacity must be given the tank so that the pulp will be retained the necessary period of time to thicken it to the required density and also to allow sufficient storage to compensate for fluctuations in the feed and discharge. This capacity may be obtained by varying either the depth or diameter to give the required cubical content.

3. The consistency of discharge possible may be closely determined by allowing a cylinder of thick but free-settling pulp to settle, taking readings at intervals of a

few hours up to the point where settling practically ceases.

4. The required area may be computed by applying the formula

$$A = \frac{2000}{24 \left(\frac{62.35R}{F - D} \right)}. \quad A \text{ is the area in square feet}$$

required to thicken 1 ton of 2000 lb. of solids to a consistency in the discharge of D (parts fluid to 1 part solids by weight), per day of 24 hr. A series of settling rates is taken on pulps ranging in consistencies from that of the proposed feed to the thickest free-settling pulp. D is taken as the ratio of fluid to solids in the thickest pulp which can be economically obtained. The greatest value for A indicated by the tests is taken as the required area. Under ordinary circumstances a factor of safety should be allowed over the calculated area to take care of changes in the character of the pulp and variations in temperature. It will be noted that this is the same formula previously given, modified to give area required instead of capacity per square foot per hour.

5. The required depth of the thickener may be ascertained by computing the capacity of the thickening zone to contain a supply of solids equal to the total capacity of the tank for the number of hours required to thicken the pulp to the density required in the discharge, and to this depth adding an allowance for the lost space due to the pitch of the drag in the thickener; also from $1\frac{1}{2}$ to $2\frac{1}{2}$ ft. for depth of feed and a further allowance for storage capacity when the discharge may be closed. The following is an illustration of the method used in computing the area and depth required in a thickener to handle 100 tons of pulp per day, thickening from 6 parts fluid to 1 part solids down to 1.12 parts fluid to 1 part solids.

The authors define in detail their method of making settling tests, and give a description of special apparatus for small-scale work. A number of tests are tabulated on slime from representative mills in different parts of the country.

Concentration

Glass Surfaces for Ore-Dressing.—The use of glass surfaces for ore concentration is attracting considerable attention in Cornwall, and numerous tests have been made which indicate the possibility of improving the present practice. Mr. W. H. TREWARTHA-JAMES writes on the subject in the February *Mining Magazine*. It is claimed that better results are obtained in dressing slime, and even coarser pulp, by the use of fluted and frosted glass surfaces. Frosted surfaces can be graded as required by treating the glass with sand of a definite size by the sand-blast machine. Fluted surfaces also are frosted in a similar manner, and the depth and shape of the flutes graded. The author describes fluted surfaces on glass $3/16$ in. thick, containing sixteen flutes per linear inch, with the depth of riffling $1/16$ in. The selection of suitable surfaces is based partly on microscopic measurement of the particles, and upon sizing and grading the particles by elutriation, confirmed by tentative tests of standard gradings on a fixed inclined surface.

The function of the frosting, pitting and fluting of the glass surface seems to be to produce proportionate retardation of that part of the pulp stream with which the glass surfaces are in contact. So far as known, these surfaces have been applied to two forms of plant: the Cornish 18-ft. round revolving frame and the Cornish fixed inclined frame. The surfaces are exceedingly sensitive to variations in the mechanical and physical conditions of the pulp, which is a practical point that

has to be translated into full-scale work before a decisive demonstration can be given. The following factors seem to be worthy of consideration:

1. The selection of a suitable glass surface, or series of surfaces, adapted to deal with uniform types of pulp which must not vary between certain limitations as to sizes of particles, pulp dilution, and the relative percentage of mineral contained.

2. The adaptation of the slope of the surface with regard to the degree of dilution of the pulp; that is, the proportion of dry pulp to water, and the other conditions mentioned.

In a further discussion of the subject, Mr. W. MORLEY MARTIN, the inventor, speaks as follows:

"Heresy though it may be, the results obtainable incline one to think that the function of specific gravity as generally understood in ore-dressing can be considered in a slightly different way and that surface retardation is, in reality, not a minor factor but the most important of all. Such retardation when properly applied appears to be proportional to the varying specific gravities of the component constituents of the solid particles in any given pulp. In other words, when scientifically applied, the difference in the rate of travel between varying specific gravities is attained with consequent separation. Obstruction of surface is not retardation: the former obstructs the whole, the latter retarding in a given order."

Mr. Martin gives the results of some tests using the same pulp on different glass surfaces, and shows the wide variation in products obtained, from which he concludes: "According to surface conditions, so are the results, and two or possibly three different surfaces on the same table may be necessary. Surely, then, if surface is paramount, to get such surface under control so as to obtain what is desired must be advantageous and superior to a chance surface with unalterable capacity and grade of product producible therefrom. The one can be made to do what you want it to do, and the other cannot."

An improvement in flotation by the agitation-froth process is published by Mr. FRED WALSH in the *Australian Mining Standard* for Feb. 3. He states that colloidal gangue matter in a pulp is frequently a serious impediment to the successful concentration of the fine sulphides, and where the proportion is very high it has prevented profitable treatment by flotation. Apparently the colloidal matter in suspension renders ineffective the frothing agents. In order to overcome this difficulty he proposes to add to the pulp a small quantity of an electrolyte of low dissociation constant, such as a weak organic acid or other weak hydron-producing electrolyte, or salts of weak organic acids, such as crude acid potassium tartrate. Tartaric or citric acid also are claimed to produce the desired effect. The electrolyte must be such as to cause no precipitation of the colloids in such a way as to coagulate mineral slime with gangue slime. Where sulphuric acid is used in the flotation process the electrolyte may be introduced before that acid, as, for example, at the grinding stage in the preparation of the pulp. Such an electrolyte, however, may be effectively employed where sulphuric acid is not used, and with or without the employment of oil or any other agent.

Old Barytes Plant Reopened.—The Virginia Zinc and Chemical Co. will begin operation shortly of the old barytes plant near Bristol, Tenn. This plant was closed in September, 1909.

The Electro Bleaching Gas Co. manufacturers of liquid chlorine announce the removal of their general offices to 18 East Forty-first Street, New York.

"Multiple Filtration" Filter and Grease Extractor

Filtration of the boiler feed water is practically a necessity in all modern, economically operated boiler plants, and more especially in plants where the hot condensate returns from the condenser and heating system is used in making up the boiler feed. Filtration removes the finally divided solids contained in the feed water, but its most important function is the extraction of the oil and greases carried over from the main engine cylinders and auxiliaries by the exhaust returns. Oil and grease, as is well known, are the most detrimental substances that can be injected into a boiler, both for efficiency and safe operation.

Effective extraction of oil and greases from water is realized only by means of successive filtration through a series of filters, each of ample capacity to permit the comparatively slow percolation of the water through the grease absorbing and extracting medium. To secure such successive or multiple filtration in a filter occupying comparatively small space, the Lagonda Manufacturing Company of Springfield, Ohio, has developed a filter and grease extractor in which the filtering medium consists of a long strip of Terry linen wound in several layers on a large spool, the successive layers being properly separated by a flexible wire mat. This construction is shown in Fig. 1. The water entering the filter chamber at the top, flows down through the perforated core of the spool and filters out in all directions through the successive layers of Terry linen into the

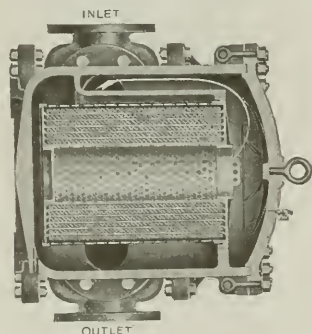


FIG. 1—FILTER AND GREASE EXTRACTOR

spacious spool chamber and the outlet. The large diameter and length of the spool provides large effective filtering area and maximum capacity of each layer with minimum resistance to the flow.

The Lagonda filter is a double unit machine consisting of two complete filters, each of which will furnish the rated capacity. The two filters are connected by double-control valves into a self-contained unit and the normal operating condition is to have one chamber in service at a time, leaving the other ready to be cut in for use when it becomes necessary to change the spool. There is, therefore, no interruption in the supply of filtered water, and in time of excessive demand, both filters can be cut in, in parallel, to double the capacity of the machine.

Under ordinary conditions the filter cloth need not be removed and cleaned oftener than every ten or fifteen days. The necessity for cleaning is indicated by the difference in pressure on the inlet and outlet side of the filtering material as indicated by the gages. This pressure difference increases as the filtering material

becomes clogged, and cleaning is advised when a difference of 10 or 12 lb. is reached.

To facilitate ease in cleaning, the covers of the filtering chambers are provided with hinged slot bolts and each chamber with a double-arm lifting davit mounted on ball bearings. When the cover bolts are loosened, the cover is easily raised and swung aside by the lower davit arm. The filtering spool is then lifted out by the self-locking block tackle suspended from the upper

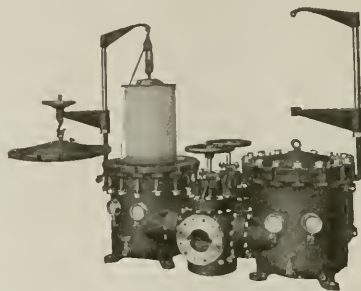


FIG. 2—GENERAL VIEW OF FILTER, SHOWING RAISING OF SPOOL

davit, as shown in Fig. 2. In this position the spool is allowed to drain for some time to prevent mussiness about the machines. As each machine is furnished with a complete extra spool, this can be inserted immediately and the fouled spool placed aside for cleaning.

To further increase the ease of cleaning and handling, a specially designed winder is furnished for unwinding and winding of the filtering cloth and spacing mat on the spool. The strip of Terry linen is washed like any piece of towelling and can be used repeatedly.

This new filter combines in a single, comparatively small unit, all the characteristics for oil extraction and filtration of the larger-space-taking filter beds. Placed between boilers and pumps, it offers one of the most simple, effective and economical means of filtering the boiler feed.

The Irite

The Gibb Instrument Company, Highland Building, Pittsburgh, Pa., has placed on the market a new instrument known as the "I-Rite," which is a very interesting combination of the principles of modern scientific pyrometry with what was sound in the old practiced furnaceman's use of his trained eye for estimating temperatures. Its principal claim for distinction is that it does not measure the furnace temperature, but measures directly the temperature of the piece under treatment. It is further distinctive in its simplicity and handiness, being of pocket size. The Gibb Instrument Company, in its new device, claims to have placed within the reach of the workman an apparatus that is simple, accurate and inexpensive.

The heat treatment of steel has ever been and, to a less extent, still is a matter of guesswork. The manufacturers of pyrometers have gone far in removing this factor. Thermoelectric pyrometers and resistance pyrometers properly installed and frequently checked give accurate measurements of the temperature at the point where they are installed.

Amazingly good results have often been obtained by the old-time furnaceman who treated steel by color, because he judged the temperature of the piece, not the furnace. A few of these men are still treating steel, and although their furnaces may be equipped with pyro-

meters, the treatment is still often done entirely by the eye. It has been claimed that while pyrometers are in general use as auxiliaries, eighty-five per cent of the actual heat treating is still done by the eye. The lack of uniformity in the product by this method is due solely to the lack of a permanent comparative color. The old-time furnaceman obtained best results only when he could carry this comparative color in his mind, and even to-day it is said that he frequently obtains better results than with the scientific method of pyrometers because by intuition he duplicates by the eye the temperature of a previously treated object.

The great obstacle against obtaining uniformity of product has been the lack of uniformity of temperature in different parts of the furnace. An instance is related of a sheet-annealing furnace which had a temperature of 900 deg. Fahr. in one part and 1800 deg. Fahr. in another. Twelve readings were taken at as many different points with as many different results. Again, an automobile part manufacturer had a number of furnaces 3 ft. x 2 ft. x 6 ft., the work from which did not run uniform. One furnace was equipped with recording pyrometers at six different points, the temperature of which fluctuated at times to the extent of 50 deg. Fahr. To best illustrate the absolute impossibility of obtaining uniformity, the electric furnace, with its uniform heat supply, cannot supply perfect distribution of heat, no matter how small the furnace. This has been recognized by the steel manufacturer to the end that he understands clearly that what he must know is not some temperature in the furnace, but directly the temperature of the material under treatment.

The new pyrometer claims to exactly duplicate the color of heated bodies and at the same time indicate the temperature on an accurately calibrated scale. It is possible for the user to read the temperature of the *piece* under treatment within 1 per cent to 2 per cent, re-

gardless of the furnace temperature. It is no longer necessary to take into account the length of time the body has been subjected to the specified temperature in order that it may assume this temperature. The pyrometer immediately shows either that the *piece* is or is not up to temperature and, in the latter event, how many degrees it must absorb to come up to the prescribed temperature.

Relative to the sensitiveness of the human eye and its ability to distinguish shades of color, an interesting experiment was carried on by Prof. E. L. Nichols of Cornell University. He placed ninety-two different shades of blue before fifty-four observers. The general average for placing these shades in proper relation was over 95 per cent. The extent of this sensitiveness is further attested in that in the practice of medicine the amount of hemoglobin in the blood is best determined by the "Hemoglobinometer," an instrument consisting of a graduated color with a calibrated scale to which is compared a drop of blood. An interesting fact in connection with this sensitiveness is that a man who is color blind can read with the same facility as one who is able to distinguish color, for the reason that while the color may not appear as red or orange he is still able to duplicate the intensity even though it appear green or blue.

The operation of the "I-Rite" is so simple that it can be as advantageously placed in the hands of the unskilled workman as the metallurgist. The construction is such that it cannot get out of order. While it is designed for the more precise temperature measurements of high-grade steels under treatment, inasmuch as it is made in two ranges, 1000-1800 deg. Fahr. and 1800-2300 deg. Fahr., it can also be used for taking the temperature of heated bodies either within or without a furnace. This makes it possible to obtain temperatures of heated steel as an ingot, billet, rail, armor plate, structural shapes, forging, casting, etc.



FIG. 1—I-RITE

Industrial Developments in Chattanooga

Much industrial news showing development in Chattanooga, Tenn., has emanated from that city in recent months—even during the business depression—but the most important announcement made for some time is the formation of the Chattanooga Steel Company, a \$2,000,000 corporation, charter for which was filed March 7. Even prior to that date several important contracts had been let, as the promoters are anxious to have the plant in operation Sept. 1.

The charter members of the corporation are C. E. James, Webster T. James, Herbert Bushnell, vice-president Citizens' National Bank; T. R. Preston, president Hamilton National Bank; W. A. Sadd, president Chattanooga Savings Bank; C. C. Nottingham, vice-president First National Bank; Z. C. Patten, Jr., president St. Elmo Bank & Trust Company, and identified with several industries.

There will be two 75-ton open-hearth furnaces producing a maximum of 336 tons per day. The blooming mill capacity will be 1000 tons. The output will be marketed for the present in a semi-finished state, but at the proper time the company will put into a finished state all its output.

The mill will be built and equipped under the supervision of the W. R. Miller Company, Pittsburgh. This concern, too, will furnish the furnaces. Contract for the blooming mill was let to the National Roll & Foundry Company, Pittsburgh, and the Westinghouse Electric Company will furnish the electric motors, which will aggregate about 6000 hp. These two contracts, it is reported, represent \$300,000.



FIG. 2—USE OF IRITE AT FURNACE

The plant will be located north of the Tennessee River from Chattanooga on a 100-acre tract, which will provide ample space for the initial buildings and future contemplated expansion. Railroad connection will be provided by an extension to the site from the spur track now being built by Mr. James from the new factory district known as "Moccasin Bend" to the trunk lines at Hixon, Tenn. As the property lies along the Tennessee River, there will be facilities for receiving water shipments of raw material, and also for shipping finished products in boats to Western and Southwestern markets. The recent decision of the Interstate Commerce Commission, recognizing the Tennessee River and encouraging the improvement of river freight service to its present good condition, was a factor in bringing the steel mill negotiations to a head, and the mill will be an important patron of the belt line now operating on regular schedule from Chattanooga to Ohio River points, for ultimate destinations such as St. Louis, Chicago, etc. The location selected will give the company nearly $\frac{1}{2}$ mile of river front, besides physical connection with the trunk lines entering Chattanooga. With this river location they can count on coal by river at a rate of 10 to 12 cents per ton as against a minimum of 40 cents by rail. On finished products they can count on a rate to Ohio River points of not to exceed \$1.50 a ton on bloom or billets. This will place their product in St. Louis on a water rate of not to exceed \$2.25 a ton and for Chicago delivery net in excess of \$2.60 per ton.

The initial plant, in all departments, will employ about 600 men, a good portion of whom will be expert rollers imported from other places. When the program is put in effect fully the employees will number from 1800 to 2000. Land around the mill site is well adapted to an industrial community, and it is anticipated that many homes for workmen will spring up there.

The buildings will be of concrete and steel. The Converse Bridge & Steel Company, Chattanooga, probably will fabricate and erect the steel frame. Construction will be facilitated by the fact that Mr. James has the structural steel, having bought it some time ago. The plant will represent the last word in construction. Electric power will be used throughout, bought from the Chattanooga & Tennessee River Power Company, operating the Hale's Bar hydroelectric development built by the late Anthony N. Brady and associates, including Mr. James.

It is stated that the completed plant (that is, when the finishing department is added) will be some 2800 ft. long and 200 ft. wide.

Chattanooga and immediate vicinity will provide sufficient pig iron, scrap iron and steel to feed the steel mill. The Chattanooga Iron & Coal Corporation is now making at least 200 tons of pig iron daily, much of which moves by river to Ohio River points for Chicago and St. Louis. The mill will use about 65 per cent scrap and 35 per cent pig.

There is a strong feeling, borne out by precedent and the logic of the situation, that the steel mill will be followed by other important allied industries. Among the first of co-ordinate character, it is pointed out that another by-product coke-oven plant and a tar-treating plant suggest themselves. While the steel mill overtops everything else under way or definitely projected, it is one of many things contributing to the present prosperity and certainty of future rapid developments of Chattanooga. Among the other items may be mentioned a \$200,000 plant of the Marion Extract Works, under way, and a \$200,000 chemical plant being built by the Chattanooga Gas Coal Products Company to develop some of their by-products.

Ferrosilicon Plant On the Mississippi

An electric furnace plant for the production of 50 per cent ferrosilicon is expected to be in operation early this spring at Keokuk, Iowa. The operating company is the Keokuk Electro Metals Co., Keokuk, Iowa. The contemplated production is 2000 to 3000 tons per year of 50 per cent ferrosilicon, and the location is favorable to the Middle Western steel plants.

The officers of the new company are: G. E. Weisenburger, president; M. H. Christopherson, vice-president, and John Dillon, secretary and treasurer. W. D. Baldwin and C. G. Comstock, president and vice-president of the Otis Elevator Co., are among the directors.

The Goldschmidt Thermit Co., 90 West Street, New York (W. C. Cuntz, general manager), are the sales agents for the new company.

Industrial Notes

Ferromanganese.—E. J. Lavino & Co., Bullitt Building, Philadelphia, Pa., have purchased the Sheridan furnace of the Berkshire Iron Works, Sheridan, Pa., and will repair it and start the manufacture of 80 per cent ferromanganese from Brazilian ore. The stack has been idle for two or three years.

New Japanese Aluminium Plant.—It is reported that a new Japanese aluminium plant is to be established at Kachigawa, near Nagoya, with a capital of \$498,000. Clay deposits near by will be used. The price of aluminium has advanced to such an extent that two of the three manufacturers of aluminium articles have had to shut down.

The Citizens Gas Company of Indianapolis expects to install in about thirty to sixty days a plant for the manufacture of sodium cyanide. The company is now extracting benzol and toluol.

Tin Smelting Begun at Perth Amboy.—Operations were commenced at the new tin smelting plant of the American Smelting & Refining Company at Perth Amboy, N. J., during the first week in March. The reverberatory smelting plant and electrolytic refinery will treat at present about 750 tons of 60 per cent tin concentrates per month. The capacity of the plant is 1200 tons per month.

Potash from Cement Plants.—The Security Cement & Lime Company, with plants at Security, Md., and at Berkeley Station, are considering the installation of an electrical precipitation system as adopted in California. Vice-President and General Manager J. J. Porter recently made a trip to California to inspect the recovery of dust there by a Portland cement company. The rock used at the Security plant is stated to be rich in potash.

Shortage of Paper Material.—The Secretary of Commerce is sending to about 4000 commercial organizations a letter inviting their co-operation in efforts to relieve the present serious shortage of paper material, according to Commerce Reports. The president of a large paper manufacturing company urges the Department of Commerce to make it known that the collecting and saving of rags and old papers would greatly better existing conditions for American manufacturers. A large part of the enormous amount of paper and paper board manufactured is burned or otherwise wasted after use. This has to be replaced by new material.

Pocket Carbon Dioxide Indicator.—The Bacharach Industrial Instrument Company, Pittsburgh, Pa., supply a pocket CO₂ indicator which has found considerable use in the Pittsburgh district, but which, perhaps,

is not so well known in other places. The indicator is conveniently arranged in a small case, and can be operated by an inexperienced man. A test takes about 2½ minutes and the operation is extremely simple.

Investigation of Phosphate in Alberta.—An investigation of a reported discovery of phosphate in Alberta has been made by the Canadian Department of Mines and the results published in Bulletin No. 12, recently issued. The author is Hugh S. de Schmid. Deposits were found in the Banff district, which are, however, unsuited to the manufacture of superphosphate by the sulphuric acid method, owing to the low content of tricalcium phosphate (43.7 per cent average), and to the large amount of silica present, 43.3 per cent average. Possibly the deposits might prove suitable for treatment by one of the thermic processes (such as electric furnace treatment) that have lately been proposed.

Mineral Production of Canada in 1915.—A preliminary report has been issued by the Department of Mines. Bull. 408. The report was prepared by John McLeish, chief of the Division of Mineral Resources and Statistics.

Testing of Hydrometers.—The Bureau of Standards has recently issued a circular (No. 16) describing the testing and securing of standards for hydrometers. Hydrometers are classified, manipulation is described and tests performed by the Bureau are included. The information is valuable and should prove very interesting.

The International Oxygen Company has issued a new catalog, No. 3, describing its Bipolar oxygen and hydrogen generator.

The Asbestos Protected Metal Company of Pittsburgh announces the opening of a new office in the Praetorian Building, Dallas, Tex., with Mr. T. R. Galey as manager thereof, and a new office in the Hurt Building, Atlanta, Ga., with Mr. J. R. Nichols as manager thereof.

The New Jersey Zinc Company, 55 Wall Street, New York, have announced the following changes in their organization, effective March 1, 1916: Mr. E. V. Peters, assistant general sales manager; Mr. A. H. Peck, sales manager; Mr. H. Hardenbergh, general purchasing agent; Mr. W. J. Lee, Jr., purchasing agent.

The United States Cast-Iron Pipe & Foundry Company announces the removal of its Southern sales and traffic offices from Chattanooga, Tenn., to 1002 American Trust and Savings Bank Building, Birmingham, Ala. This change becomes effective April 1, 1916.

The Kansas City Testing Laboratory, Kansas City, Mo., has issued an interesting pamphlet descriptive of petroleum and its uses. The pamphlet contains much valuable information condensed into a small space, and includes analyses of the natural content of typical crude oils, an outline of typical refinery practice and various specifications and tables.

New Chemical Laboratory for Detroit.—A fully equipped commercial laboratory has been opened at 445 Howard Street, Detroit, by the Wolverine Laboratories Company. L. F. Miller, formerly chief chemist of the Timken-Detroit Axle Company, will be in direct charge. The company will specialize in analyses of iron, steel, coal, oils and non-ferrous alloys.

The firm of **L. O. Koven & Brother**, Jersey City, N. J., will in a short time remove its main office from 50 Cliff Street, New York, to 154 Ogden Avenue, Jersey City, N. J. This change has been in contemplation for some time. The new office building, which has been recently reconstructed, has four floors and is well equipped.

Personal

Mr. C. G. Atwater of the Barrett Company, New York, presented an illustrated lecture on "the utilization of by-products from the manufacture of coke" at a meeting of the Engineers' Society of Western Pennsylvania, held in Pittsburgh, March 28, 1916.

Mr. A. L. Blomfield, for many years in the employ of Bewick-Moring & Co., as metallurgist, and for the last eight years mill superintendent of the Golden Cycle mill at Colorado Springs, has become associated with The Dorr Company, successors to The Dorr Cyanide Machinery Company. Mr. Blomfield has taken charge of the metallurgical consulting work for the company, with headquarters at Denver. He retains connection with the Golden Cycle mill as general superintendent.

Mr. W. Walley Davis of Harrisburg, Pa., superintendent of the Pennsylvania district plants of the Semet-Solvay Company, has been appointed superintendent of the Chicago district plants and manager of the By-Products Coke Corporation with headquarters in Chicago. Mr. Davis, who has been in charge of the plants at Steelton, Lebanon and Dunbar, Pa., since 1907, came to Harrisburg from Milwaukee, where he was in charge of coke plants.

Mr. Harry L. Day has tendered his resignation as general manager for the Federal Mining & Smelting Company, one of the largest operating companies in the Coeur d'Alene district, Idaho. He will be succeeded by Mr. F. H. Brownell of Seattle, Wash., formerly president of the company and now chairman of the board.

Mr. Herbert H. Dow, general manager of the Dow Chemical Co., Midland, Mich., was tendered an agreeable surprise on his fiftieth birthday, Saturday, Feb. 25. Several employees of the company, mostly heads of departments, arranged a surprise banquet for him at the Wenonah Hotel in Bay City, Mich.

Mr. C. A. Grasselli, who has served a long time as president of the Grasselli Chemical Company, has retired from that position to become chairman of the newly created board of directors. Mr. Grasselli's son, T. E. Grasselli, succeeds him as president of the company.

Mr. Glenn N. Hastings of Chicago has been appointed Middle West representative of Hamilton & Hansel, New York, agents for the Rennerfelt electric furnace.

Dr. Carl Hering, consulting engineer of Philadelphia, Pa., has removed his office to 210 South 13th Street, where more elaborate laboratory facilities are at his disposal.

Mr. Robert M. Keeney has joined the forces of the Snyder Electric Furnace Company of Chicago, where he will have charge of the development work. Mr. Keeney has had a broad experience in electric furnace research, covering the production of iron, steel and ferroalloys in the electric furnace, and the electric smelting of lead, copper and zinc ores. His work has been especially directed toward the production of ferroalloys and electric smelting. In this connection he visited many electric furnace plants in Sweden, England, France and Germany. Before his connection with the Snyder Electric Furnace Company, Mr. Keeney was electrometallurgist of the U. S. Bureau of Mines, at Pittsburgh and Salt Lake City, mill superintendent of the Baker Mines Company, Cornucopia, Ore., and metallurgist of the Standard Chemical Company, Canonsburg, Pa. In the latter connection Mr. Keeney was engaged in the production of ferro-

vanadium and developed a process for the manufacture of ferrouuranium. While in the Western States, Mr. Keeney made an extended study of the application of the electric furnace to the smelting of ores, flotation concentrate, and cyanide precipitate.

Mr. W. A. Neill, for many years engineer of the mining department of Allis-Chalmers Company, has moved to Denver and became associated with The Dorr Company, successors to The Dorr Cyanide Machinery Company as mechanical engineer.

Mr. E. L. Newhouse, Jr., is general manager for the newly organized Garfield Chemical and Manufacturing Company, which will produce sulphuric acid in the vicinity of Salt Lake City, Utah.

Mr. Nathan Owitz has been appointed sales manager of the J. P. Devine Company of Buffalo, N. Y., manufacturers of vacuum drying apparatus and chemical equipment, and will be located at the main office and works at Buffalo. Mr. Owitz was formerly with the Wheeler Condenser & Engineering Company of Carteret, N. J.

The marriage is announced of Dr. Carl G. Schluederberg of the Westinghouse Electric & Mfg. Co., Pittsburgh, on Feb. 25, 1916, to Miss Roberta Skene.

Mr. M. Yamashita, mining engineer for Mitsubishi & Co. of Japan, is visiting ore-dressing plants in Colorado, New Mexico and Arizona on his return to Japan. He expects to sail from San Francisco on March 25.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Aqueous Bath Cathodes

(Continued)

583,255, May 25, 1897, Ernest Auguste Georges, called Charles Street, of Paris, France, assignor to the Electro-Metallurgical Company, Limited, of London, England.

Relates to cathodes for electrodeposition; the cathode is preferably a thin sheet of flexible metal capable of being rolled upon itself. The cathode is preferably rolled into a cylinder, and the deposit produced upon the outer surface. Upon rolling the cathode into a cylinder of smaller diameter, the deposit peels off.

591,571, Oct. 12, 1897, Joseph W. Richards and Charles W. Roepper of Bethlehem, Pa.

Relates to the electrolytic recovery of metals from their solutions, and employs a highly porous cathode, such as shavings, masses of excelsior, matted or tangled threads, etc., which have been made conducting by coating with graphite, or by soaking in a solution from which metal can be precipitated either by reduction, such as a silvering solution, or by precipitation, such as gold from gold chlorid and ferrous sulfate, etc. The cathode may also consist of such substances as interlaced wood fiber, corn-pith, masses of linen, paper, hemp, jute or cocoa fiber matted or woven, fine flaky or granular masses such as wood-sawdust, etc., which have been made conducting. The mass of loose material is held in a coarse bag, such as netting, and during deposition, the metal deposits throughout the mass on all the coated surfaces. After the deposition, the deposit is washed and dried, and may then be ignited.

The residue is collected in any suitable way, or may be melted down in a crucible under a flux, such as borax, etc.

602,212, April 12, 1898, Emile Louis Dessolle, of Epinay sur Seine, France.

Relates to making electrodeposited sheets or hollow forms, such as reflector shades, etc., which may or may not be gold or silver plated. The cathode surface is coated electrolytically with either platinum, or nickel, or gold, or other metal capable of sufficiently occluding hydrogen. The coated cathode is then connected as a cathode and immersed in an acid or alkaline electrolyte, using an insoluble anode. The cathode is agitated to mechanically dislodge bubbles of free hydrogen, this electrolysis being carried out at from two and one-half to three volts. After sufficient hydrogen has been occluded, the cathode is removed and polished. It is then immersed in the solution from which the sheet or hollow form is to be made, and deposition of the metal effected, the cathode being continually agitated during deposition. After it is finished, the deposit may be readily stripped from the occluded hydrogen surface. For an article made of copper, the cathode surface should be platinum, while for silver, a cathode surface of nickel or gold is preferred.

630,796, Aug. 8, 1899, Hermann Becker of Paris, France.

Relates to preparing cathodes for the easy removal of deposits. The cathode is preferably highly polished silver, or silver-plated metal, which is rubbed with flowers of sulfur, or precipitated sulfur, or a sulfid coating may be produced thereon by any other suitable method. The sulfid coating may be polished after it is produced if desired. In the treatment of cyanid solutions for the recovery of gold, silver, etc., the cathodes may be of sheets of iron, copper, lead, nickel, or of iron tinned, coppered, nickel, or the like, the surfaces being sulfured and polished as described above. The deposit acquires the polish of the cathode, and is readily removed therefrom. With very-thin deposits of gold, the gold may have a reinforcing deposit of copper to facilitate its removal.

Book Reviews

The Metallography and Heat Treatment of Iron and Steel. By Albert Sauveur. Royal octavo (17 by 27 cm.), 486 pages, 438 illustrations; price \$6.00. Boston: Sauveur & Boylston.

This is a revised second edition of Professor Sauveur's well-known book on metallography of iron and steel. It is clearly written, very practical, beautifully illustrated, prettily printed. The new edition has had almost every chapter revised, over fifty pages of new matter and 100 illustrations added, and the book entirely reset. We commend the postponement of the phase rule and equilibrium diagram to the closing chapters, when the student has acquired familiarity with the metallographic facts which these principles co-ordinate.

It is a well-written and extremely useful book, and the new edition is superior to the former.

The "Mechanical World" Electrical Pocket Book for 1916. 298 pages. 130 illustrations. Price, 25 cents. Manchester: Emmott & Company, Ltd., Baltimore. The Norman, Remington Co.

A large variety of subjects are taken up in this little book and the space devoted to each is consequently not large. The information is given in very concise form and a great many of the subjects are just touched upon. Among the new features of the present issue is a section on switch gears and switch boards. A new section is given on earthing while the whole book has been generally revised. The book contains sufficient tables for ordinary work, is clearly written and should be useful.

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One Function of Scientific and Engineering Societies in Democracy

Within the next two weeks the two largest national chemical societies of this country will hold their spring meetings. The American Chemical Society will meet at Urbana-Champaign in connection with the dedication of the new Chemistry Building of the University of Illinois. The American Electrochemical Society will meet a week later at Washington, D. C. Really remarkable programs have been arranged for both meetings—truly representative of the aims and spirit of the two societies. That both meetings will be highly successful there can be no doubt. However, as the full report of both conventions will appear in our next issue, we will not prophesy, but may be permitted instead to indulge, just for a moment, in a little reminiscence. The incident dates back some few years. It happened in the old Chemists' Club in New York—this will fix the date sufficiently.

He was a moderately able man and a fair chemist, engaged in manufacture. "This sort of thing," he said, referring to a chemical meeting which had just adjourned, "is all twaddle. There's nothing in it. Lot of wind bags get up and read papers and sputter, just to advertise themselves. Nobody tells anything that, so far as he is concerned, is of value. Why should he? In chemical industry, if you have a good thing you keep it to yourself. That's what you're there for. This idea of falling upon a man's neck and kissing him and talking to him like a school girl just because he is a competitor and is trying all the time to get your business away from you is piffle; arrant piffle!"

It may be that the gentleman's wife was not treating him very well, which oftentimes embitters the vision; it may be that he had a sour stomach, and it affected his disposition; perhaps he felt the need of a drink and the pill-wallah wouldn't let him take it, and then again, just as likely as not, this was what he really thought. He dropped out of sight a few years ago.

The trouble with him was that he was structurally too narrow-minded and too short-sighted to be a part of any movement that makes for progress. Let us consider what would happen to manufacturers now if they were to hold to secrecy in all things. We have had plenty of such experience. They joined in a lobby in Congress occasionally, but aside from that they were constant enemies of one another. Business was a battle and competitors were foes. The spy system was in full flower, and laborers were bribed to tell foolish secrets that a properly equipped research laboratory would soon prove to be the unprofitable enterprise that it is. It is still in thorough accord with the philosophy of the "practical" man who doesn't want any "theorists"

around him. With the craft and astuteness of the criminal injected into industry, the morale and standing of the men engaged in it degenerate. Industry, instead of building up a nation, which it can do, drags it down, which it can do even more easily.

The men who speak and read papers at meetings of the societies are not to be scorned for the very reason that they are the best men we have—the men of the widest knowledge, and who have achieved the greatest measures of success. The information that they give is of real and business value to them time and again.

The science of chemistry is the study of the ways of stuff, and these ways are too many and too different for any one man to learn. That is why it is better to draw information from a common source, to the end that each may make greater advances.

Two competitors may make the same product, and be in hot competition after the same markets, but if their raw materials are different, as they often are, the competition begins only after the product is made—between their sales departments.

The New York Section of the American Chemical Society has held three meetings (the last of which is reported elsewhere in this issue) to discuss the relations of the universities to industry, and the growing affinities between them were shown at each meeting. The distinctive mark of chemistry in America is that those engaged in pure research, on the one hand, and those engaged in industry on the other, have not gone their different ways separately, and have not developed those "class differences" which both the anarchists and the chemical world in many places acclaim and boast. "Science," said Dr. Levene of the Rockefeller Institute at the last meeting, "follows the economic development of a people." This is unprejudiced testimony, and is said with authority.

If chemical industry should take the narrow view of secrecy in this country and hold aloof from the learned societies of science, we can count upon its speedy failure with the same certainty that the wife of the drunkard can count on her husband's loss of his job.

Let us now make a little survey of the situation and see how matters stand. We live in a country of vast area, of miscellaneous population, of the greatest possible variation in density, and loosely governed. The energy available for constructive work in relation to government is largely exhausted in a quadriennial quarrel for the control of offices. The merit of the form is the avoidance of the danger of suppressing the development and growth of the individual. Its demerit is waste of energy and loss of direction. Its result is that government follows public opinion, and public opinion is not controlled—it drifts. Sometimes it drifts over dangerous shoals. Because of this drifting, industries have been built up artificially at one time and ruined, ruthlessly, at another. Human welfare has suffered and deteriorated as well as advanced under it. In so far as newspapers direct public opinion, there is no standard of editorial righteousness. That most dangerous of all practices, the appeal to wrath, which makes for

disorder and degeneracy of mind, is wholly unbridled. It is even encouraged—to develop circulation.

The source of the power that rules us as a nation, defends us, negotiates for us and looks ahead for us is public opinion. If that is wise we need not fear. If it is foolish we shall do well to fear.

Leaders of public opinion are not elected to perform that function. To lead public opinion is an entirely free scramble. The man on the soap box on the street corner is in the race for leadership. So is the President of the United States. So also is the able lawyer with a fat retainer in his pocket to forward the interest of the client who wants to work politics for his own benefit. He is far more dangerous than the man on the soap box. He does not appeal to the mob. He appeals to that enlightened stratum of society of which we hold ourselves to be a part. We are more easily molded under the Iago-like dexterity of the "distinguished publicist" with a legal fee in his pocket than are the men in the crowd around the soap box. They listen for a while and then go home and forget about it—mostly. We listen to the well-chosen remarks of the great lawyer, who is such an enemy to all that is evil (but with his secret fee in his pocket), and we go home with the conviction that "there is something in what he says." And we are right; there is a lot in what he says. It is so patriotic and intelligent that he wins us. The poison that we swallow along with all the patriotic and intelligent talk is not labeled. We take it along with the good. We think it good and, God help us! we like it. Of course, if we were informed, and had thought about his principal subject, which seemed so incidental in his remarks, he would have plead with us in vain. In the language of the street, we should have been "onto him." But if we are not informed, we are very likely to follow like sheep, and, indeed, if public opinion is to be called the voice of the mob, then we are a part of the mob.

Here may be found the great value of scientific societies in public affairs. The impression prevails that science does not strive to put facts out of their right relation to each other and so pervert the truth. The privileges of lawyers in this respect have cost them, as a body, a considerable measure of public confidence. The man of science, except when he offers expert testimony in court, is supposed to be peculiarly free from this defect. The findings of science are believed to have been reached with honest intent. President Herty of the American Chemical Society said at the last meeting of the New York Section, in regard to the Hill bill now before Congress to meet the dyestuff situation, that Southern cotton manufacturers had only asked concerning the bill, who had prepared it. They were told that it had been done by a special committee of the American Chemical Society. "Then," said they, after a hasty examination, "we are in favor of it." They were not fearful of politics back of it; they knew it was intelligently prepared, and they believed in the integrity of the men composing the committee.

In the haze of thought and the conflict of politics; in the chicanery of special interests, and the rumble of

the slow-moving and cranky steering gear of the ship of state, a new responsibility has devolved upon the great scientific and engineering societies. It is to tell the truth, from the standpoint of science, about those things which pertain to human welfare and progress in words that all may understand. Wherever science touches humanity there these learned societies may lead in public opinion. Their business is the spread of enlightenment.

Chemistry and Congress

Ordinarily the *Congressional Record* does not offer particularly interesting reading, especially to chemists. But if our readers will take the trouble to look up No. 86 of Vol. 53, covering the proceedings of March 31, they will be rewarded by finding in it two unusually able speeches, one by Representative Longworth for the Hill dyestuff bill, the other by Senator Underwood on the atmospheric nitrogen fixation problem. Yet it would be wrong to consider these speeches as isolated exceptions. They are signs of the times. On railroad trains, in clubs, in restaurants, wherever people come together, we hear them talk of chemistry.

While we are going to press we learn of the defeat in the Senate of the Lodge dyestuff-tariff amendment to the sugar bill, and Senator Underwood is stated to have been chiefly responsible for the defeat. As the official reports have not yet come to hand, we cannot believe that the same Senator Underwood who made that speech on the nitrogen problem two weeks ago, should have made unqualifiedly such statements on the dyestuff situation as he is reported to have made in some of the newspapers. It seems unbelievable that this should be the end of the dyestuff tariff fight in the present Congress. For the present we prefer to take it as part of the political game. But the situation needs watching. The time is critical.

Coke Ovens as Gas Producers

About eight years ago some amusement was caused by the announcement that blast furnaces were being blown in at the Gary plant of the United States Steel Corporation, not because pig iron was needed, but because the gas was required. The first Gary furnace was blown in Dec. 21, 1908, the second Dec. 29, and the third Jan. 26, 1909, while steel was not made until Feb. 3. The first furnaces were operated as gas producers rather than as pig-iron producers.

Now we have a large retort coke plant that is to be located as a gas producer rather than as a coke producer. While the coke output will, of course, be as valuable and useful as under other circumstances, it is understood that the location and size of the Clairton plant to be built by the Steel Corporation are determined largely by the gas requirements of the Corporation's Pittsburgh district steel works, now that serious decreases in the natural gas supply in the next couple of years must be faced. Except for certain merchant coke plants, all retort coke oven plants have been adjusted in size to the requirements of the blast furnaces at which they were built. This

policy is to be departed from at Clairton, where there are three blast furnaces, while the coke plant to be built is to comprise 640 retorts and eventually 1300. The appropriation under which construction work will shortly be started covers 200 ovens. The output of 1300 retort ovens should be in the neighborhood of 5,000,000 tons of coke annually, about ten times the requirements of the three Clairton blast furnaces. At 4000 cu. ft. of gas per ton of coke the gas output would be 20,000,000 M cu. ft. annually. The country's natural gas production has lately been running at a trifle less than 600,000,000 M cu. ft., so that the Clairton gas, though of relatively low calorific value, will be a distinct item.

Coal Refining

As a problem in chemical engineering the refining of coal offers some attractive possibilities. Coal is one of the few mineral products used largely in the raw state, despite the fact that the wastefulness of the process has long been recognized. Like petroleum, which no one thinks of using to any extent in the raw state, coal is a complex substance susceptible of separation into many valuable products, with the fixed carbon left in improved form for fuel.

A Western problem of this type is the refining of lignite—a coal high in moisture and volatile matter, and wholly unsuited to efficient consumption in the raw state. Bulletin 89 of the U. S. Bureau of Mines is devoted to the efficient use of lignite, recording studies made in North Dakota; and elsewhere we have referred to extensive work being done in Colorado. If magnitude is a factor in making a proposition attractive, this one must be expressed in superlative terms, for the bulletin mentioned conveys the information that in North Dakota alone the deposits cover 32,000 square miles and are "capable of producing in all several hundred billions of tons of lignite."

Gas, ammonia and tar are the products of the destructive distillation of lignite, and the briquetted residue is in far better shape, physically and chemically, for use as fuel than was the original coal. The tar obtained is an important product, for from it may be fractionated light and heavy oils and pitch. In the Colorado work an effort is being made to introduce some of these distillates as flotation oils. It is claimed that since they are fractions distilled at definite temperatures, uniformity can be maintained in the products, and that a suitable combination once determined can be duplicated without difficulty. This would be an important consummation, for one of the reported difficulties in flotation work has been the lack of uniformity in successive lots of oil bought.

Coal refining offers an opportunity for industrial development in the West, for lignites are abundant in North Dakota, Montana, Wyoming, Colorado, Texas and other Western States. The development will be slow, for outlets must be found for the products and related new industries must be established. Pioneer work has commenced, however, and the results will indicate how rapid an expansion can be anticipated.

Readers' Views and Comments

Cheap Power from Central Stations for Electrochemical Work—Possibilities of the Pacific Northwest

To the Editor of Metallurgical & Chemical Engineering

SIR:—In your issue of March 15, in a letter from "A. C." of Brooklyn, N. Y., he states: "Finally, it ought to be possible to buy current from some of the great central station companies in our larger cities. Prices approximating $\frac{1}{2}$ cent per kilowatt-hour have been rumored. Of course, such a rate would only apply to those hours of the day when the regular light and power load is unusually light."

I have noted in the technical papers from time to time recently similar statements to the effect that power at one-half cent per kilowatt-hour should be available.

In this connection, I wish to call attention to the rates of the Puget Sound Traction, Light & Power Company, operating in Seattle and the Puget Sound territory. Our water power plants now have an installed capacity of 74,000 horsepower, supplemented by steam relays with capacity of 34,000 horsepower. Our regular commercial power rates for loads in excess of 101 horsepower for continuous use is $\frac{1}{2}$ cent per kilowatt-hour. To electrochemical or electrometallurgical processes, or other concerns using large blocks of power continuously we can quote a very materially lower rate and are in the field for such business.

We have in contemplation two additional waterpower developments which will be made as quickly as the market demands warrant, where from 75,000 to 150,000 additional horsepower can be obtained, depending upon the method of development decided upon. With the output of the Niagara Falls plants practically all sold, it is believed that the Pacific Northwest offers better opportunities for low cost electric power than any other part of the United States to-day.

It is realized that the cost of electric power in many of the industries is not the dominating feature, but in the electrochemical and metallurgical field it is known that the percentage of power cost to the final cost of the manufactured article is relatively high, and for this reason it is believed that the extremely low rates available here should be of much interest.

W. E. HERRING.

Puget Sound Traction, Light & Power Co., Seattle, Wash.

"All Around the Edges"

To the Editor of Metallurgical & Chemical Engineering

SIR:—At the risk of your already knowing the story of how "Shorty" McCabe met his nephews coming from abroad, I am repeating it here, since it seems to express the attitude of some in the East as to the present hydroelectric power situation in the United States.

Shorty was a New Yorker; had never been further West than Albany—as a fact thought anything beyond the State capitol was the "wild and wooly West." Broadway, Fifth Avenue and Forty-second Street were his world.

One day Shorty met his nephews coming in on a trans-Atlantic steamer.

The young fellows came off the gang plank, full of enthusiasm, pleased to set their feet on terra firma again. To be sure that they by chance had not got on

the wrong steamer in Liverpool, they asked Shorty, after greeting him: "Is this United States?"

"No, indeed," replied Shorty, "this is not United States; this is little, old New York."

The nephews, much puzzled, asked, "Where, then, is United States?" To which they received the true and typical reply, "Why, United States is all around the edges."

Is there not some similarity in Shorty's attitude regarding New York and the rest of the country to that taken at present by many of the electrochemical power consumers and others in the East, as to the hydroelectric powers of United States.

From reports of various meetings held in the East I notice a howl and clamor regarding the lack of hydroelectric power, and the claimed impossibility of obtaining same, due to the attitude of the government.

To be sure the government may justly, or unjustly, put restrictions on the development of power at Niagara Falls. But there is still something "all around the edges," containing large quantities of cheap available hydroelectric power, located either inland on railway, or on tidewater.

It is worth remembering in this connection, that 40 per cent of all the hydroelectric power of the United States is located west of the Rockies, and everybody familiar with the situation there can name a number of power sites that are awaiting development, and are besides cheap developments, with water assured for power 365 days of the year.

Among the most noted ones at present, is the Speel River project in Alaska, where 100,000 horsepower, located on tidewater, are awaiting development. This power is situated in a manner identical with some of the famous Norwegian developments, like the one at Tyso, near Odda.

The Columbia River development at The Dalles, is another project on tidewater. Close to a million horsepower can be obtained there, the most of which is available twelve months of the year. Here power has been offered in large blocks at a price less than \$10 per horsepower-year.

The Great Western Power Company, the largest individual power producer on the Pacific Coast at the present time, has some 100,000 horsepower already developed, and is prepared to enter into contracts with power consumers for 500,000 horsepower more, at low rates, either at the power sites, on the Western Pacific Railroad, or on tidewater on San Francisco Bay.

The poor, abused company, mentioned by one of the speakers at Niagara Falls, which had to go to Europe for additional power, due to dearth of same in the United States, could not have had its ear close to the ground? Perhaps the cause in reality was another. Wasn't it a question of waging a war in the enemies' country, and not lack of power in United States?

The government's attitude may not always be what seems the wisest in regard to Niagara Falls, but in spite of that, there is still power "all around the edges," aggregating about 1,500,000 horsepower, if only the three above mentioned developments are considered, and these, compared with Niagara Falls, make a good showing.

The industrial preparedness of the United States is indeed important, but how can this be even launched as a valid argument in favor of increasing the power developments, legitimate as this may be, at Niagara Falls,

with only a narrow strip of water between us and a potential enemy.

Unfortunately we cannot prescribe with whom we may have a scrap. If with England and Canada, which I hope will never occur, what would a few shots from a cannon do to our industrial preparedness at Niagara Falls?

Few places in the world are as favorably located as Niagara Falls for electrochemical industries, but I feel equally certain that some places "around the edges" will in the next decade develop, in a manner that may to some extent rival the electrochemical supremacy of Niagara Falls.

J. W. BECKMAN.

San Francisco, Cal.

So Much Fire and So Little Light

To the Editor of Metallurgical & Chemical Engineering

SIR:—The *New Republic* is a journal of opinion and so far as I am aware it has no interests to conciliate. The editors of it are not pressed for time and there is no scramble in its pleasant offices over in the Chelsea district of New York to get a beat on news. Its articles are wrought with consummate literary craftsmanship, and the sentences that compose them follow one another in such urbane and graceful procession as to give the lover of English a sense of pleasurable envy, whether he agrees or not. In considering a book called *The Pillar of Fire* by Seymour Deming, a very radical work and full of prophecy of the Kingdom of Wrath unless we mend our ways. Mr. Randolph Bourne says: "Mr. Deming moves you but he leaves you in the end more entertained than persuaded. His prophetic fire is so much fire and so little light." The merits of the book are then set forth but the fatal words are said: "So much fire and so little light." And it fitly describes the labor situation to-day. The interesting point is developed in the review that the radical of to-day, as he enters into constructive thought, is speedily denounced as a snob and told to "go down into the labor unions and socialist locals and learn of the workmen. Let him touch the great heart of the people. . . . Only by humbly working up through the actual labor movement will the young radical learn his job."

Well, time and again the young radical does go down to the labor unions and socialist locals—and it is right and proper that he should—but when he gets there he finds his welcome to be gaged according to his acceptance of every doctrine laid down; the bad with the good, the hate with the sympathy, and the support of every strike as soon as violence begins. The one thing he must not be is "intellectual." Everything is a fight, everything is a struggle, and the way to win is to swat and swat hard. Trouble with those highbrows is, they're floppy. First they agree and then when something comes up they don't agree and they make a fuss. They're no good. This is often the union point of view.

Then the young radical, unless he has more character than most men is likely to be swept along in the stream of hate, and he grows to lean more and more toward dynamite and away from law and order.

Now we live in a world of misfits and we cannot hope that society will do much more than stagger along under the great burden that it has to carry until we find a better way of fitting jobs to men than we know of to-day. But we venture the assertion that what holds us back from progress and begets the outbursts of disorder is feeble-mindedness more than anything else.

We are all feeble-minded in one way or another. The aesthetic feeble-mindedness of manufacturers is proven by their works, the ugliness and shoddy look of factories, the dirt and general befoulment that factories produce,

which the enrichment of art dealers by those who have prospered in manufacture and even the maintenance of private picture galleries do not controvert. The social feeble-mindedness displayed by the introduction of workmen who, for lack of proficiency in English are unable to defend themselves, to take the places of competent men who may have struck for good and sufficient reasons, is too evident to need elucidation. Some few men are so gifted that they seem to be feeble-minded only in regard to *vers libre* or cubist painting, but they are rare birds indeed. What mortal has a right to think that he can build a factory, ruin the health and the hope of his operatives, and at the same time expect to have his works endure? He would not do this unless that portion of his equipment which functions as sympathy were either atrophied or congenitally lacking. We who bear the odium of the radicals by being what they call "capitalistic" need not boast; there is plenty of feeble-mindedness among us.

Now come those that have begun to boast that they are the proletariat. How much of this defect of feeble-mindedness have they to carry along with them and support? They get all those who are not lucky enough to have somebody support them, except such as gravitate to the criminal class. When the father dies, in most cases there is not much left after the funeral expenses are paid. What happens to the boys and girls that are, as we say, "not very bright"? They look for work. Gradually, with the slight demands made upon the mind by a great deal of machinery, they become "hands" in manufacturing of one sort or another. If the boys are strong they may get a job in the mines when men are wanted. There are a great many such persons that have wit enough to keep at a job and can do, say, three-quarters of a man's work. They pay their dues and join the union. They draw the minimum wage for a day's work and perform three-quarters. That brings the standard down 25 per cent. Now, instead of bringing enlightenment to bear upon the situation employers have frequently brought craft and force. The three-quarter men do not know that they are limited in capacity, and their comrades stand by them. The sympathy between the three-quarter men and the whole men is greater than the sympathy between the whole men and the employers. Then comes trouble. The inadequates follow the vicious, and soon the strike vote is taken.

The only way to deal with the inadequates is to provide for them. There should be a place where a three-quarter man could do his three-quarters in a full day's time. Of course, he would have no opportunity for advancement. At the same time there should be a place where a 100 per cent man could do a full day's work at not much better wages but with a chance for extra pay and from which group the men for the higher positions should be drawn. This would sift out the vigorous from the inert, the capable from the incapable; it would separate the culls.

It should be no disgrace to be among the three-quarter men. Many of us would find ourselves in that gang if we had had no chances. It would not of necessity mean that the men were feeble-minded except as to that particular kind of work. Some of them might be rarely gifted in other respects and if an opportunity to use their talents could be found elsewhere, both employer and employees would be anxious to secure it for them. Advancement and authority, however, would only go to the whole men.

Could such an arrangement be made with the Western Federation of Miners? Certainly not. Or with a political body like the American Federation of Labor? Surely not, with politics all tangled up with it. It will require a new angle of vision; something, perhaps, like

what seems to be growing in Colorado. But think what it would do! The drag upon labor unions would be lifted; the three-quarter men would be provided for and constructive plans for increased output along with betterment of labor conditions could be undertaken with the whole men. The agitator with nothing but anger and disorder to offer would have less standing. The whole men, who would naturally lead, would have a higher average intelligence and while their demands might be more astutely drawn, they would be more reasonable in them. Many employers would have to be converted from their present ways and many others would do well to give up in despair rather than try to administer industrial affairs under enlightened conditions; but if we want to make advancement in industrial life in this country we must make up our minds to face enlightened conditions in the labor situation.

Modern machinery is not designed to develop latent intelligence among operatives. The great desideratum is to make a machine at once "simple to operate" and "fool proof." These are good qualities, but they do not exercise the brain or develop the general intelligence of the operative. That is a defect of merit. Machinery does not improve the quality of labor.

So long as organized labor is burdened with its great load of feeble-mindedness it is bound to protect its weaklings because they are not otherwise protected. We cannot call this attitude of mind either wrong or vicious or evil. And so long as this burden is upon labor it is unfair to expect it to close its eyes to the advocates of disorder or to engage in constructive work with the administrative force of great industries. So we must devise a means to give the man who can do things a chance to better himself while the burden of carrying the man who cannot do as much is lifted from his shoulders.

If this is accomplished the time may come when the administration of a corporation may invite representatives of their laborers to be present at annual meetings of stockholders to explain what provision is made for living conditions at the works and what remains to be done, as an offset to demands for more dividends. Then if stockholders still demand greater division of earnings in spite of an agreement between the administration and the labor force, they can take the consequences. But they are not likely to. Capital is not vicious, any more than is labor, in its original intent. But sometimes it is stupid, just as labor unions are sometimes stupid and in a dull, blind, unthinking way it wants to grow—like a cancer. A cancer doesn't care about doing any harm or about hurting anybody. It just minds its own business—and wants to grow. That is why it is so dangerous.

ELLWOOD HENDRICK.

NEW YORK CITY.

Program of Washington Meeting of American Electrochemical Society

The annual meeting of the American Electrochemical Society will be held at Washington, D. C., from Thursday to Saturday, April 27 to 29, 1916. Headquarters will be at the New Willard Hotel, Pennsylvania Avenue, Fourteenth and F Streets.

The American Institute of Electrical Engineers, which will hold a meeting on Wednesday, April 26, at the New Willard Hotel, has extended a cordial invitation to the members of the American Electrochemical Society to attend this meeting. Reciprocally, the members of the American Institute of Electrical Engineers are cordially invited to attend the sessions of the American Electrochemical Society, particularly those of Thursday, which have been arranged to be of particular interest to electrical engineers.

The American Electrochemical Society will hold three sessions on Thursday (morning, afternoon and evening) and two sessions on Friday (morning and evening), all of these at the New Willard Hotel, while a long morning session is scheduled for Saturday at the Bureau of Standards.

The program is so crowded with papers, symposiums and lectures that no social functions have been scheduled except the lunches on Thursday at the New Willard Hotel and on Saturday at the Bureau of Standards, and the excursion to Mount Vernon on Friday afternoon.

Wednesday, April 26, 1916.—Meeting of American Institute of Electrical Engineers, to which the members of the American Electrochemical Society have been cordially invited, at 2 p. m. and 8.15 p. m., at the New Willard Hotel. The program of the two sessions is as follows:

Address by President JOHN J. CARTY.

"Electrochemical Industries and their Interest in the Development of Water Power." By LAWRENCE ADDICKS. "Water Power Development and the Food Problems." By H. S. CUSHMAN.

"Relation of Water Power to Increase Transportation." By L. B. STILLWELL.

"The Relation of Water Power to the National Defense." By W. R. WHITNEY.

"The Water Power Situation, Including Its Financial Aspects." By GANO DUNN.

Thursday, April 27, 1916; 9.30 A. M.—Annual business meeting of the American Electrochemical Society in the Red Room of the New Willard Hotel. (Reports of Board of Directors, announcement of annual election, miscellaneous business.)

Presidential address by the retiring president, LAWRENCE ADDICKS.

Symposium on co-operation in industrial research: LAWRENCE ADDICKS, the professional society; F. A. LIDBURY, the professional society; W. D. BANCROFT, the university; W. H. WALKER, the university; D. A. LYON, the Government; L. H. BAEKELAND, the corporation; W. R. WHITNEY, the corporation.

"The Detectors in Wireless Telegraphy." By W. D. BANCROFT.

"Hydrogen for Military Purposes." By E. D. ARDERY.

"Liquid Chlorine." By G. ORNSTEIN.

"Magnesium." By W. M. GROSVENOR.

12.30 P. M.—Luncheon in the New Willard Hotel.

2 P. M.—Meeting in Red Room of the New Willard Hotel.

Symposium on Niagara Falls Power and the American Industries:

"The Power Development." By I. R. EDMANDS.

"Electric Furnace Products." By F. J. TONE.

"The Chemical Industries." By A. H. HOOKER.

"The Nitrogen Question." By W. S. LANDIS.

Illustrated address, "Reclamation Service Water Power." By Director A. P. DAVIS, chief of the Reclamation Service.

"The Brittleness of Annealed Copper." By W. E. RUDER.

"Cobalt as an Element for Thermocouples." By O. L. KOWALKE.

"Electrical Resistance of Copper-Nickel Alloys." By F. M. SEBAST and G. L. GRAY.

"Faults in the Small Electric Arc Furnace."

"The Rennerfeldt Electric Arc Furnace." By C. H. VOM BAUR.

8.15 P. M.—Meeting in the Red Room of the New Willard Hotel.

Illustrated lecture by J. H. PIERCE, "Water Power Development for Electrochemical Purposes."

Friday, April 28, 1916; 9.30 A. M.—Meeting in the Red Room of the New Willard Hotel. The following papers will be read and discussed:

"The Passive State of Metals." By C. W. BENNETT and W. S. BURNHAM.

"Overvoltage." By C. W. BENNETT.

"Overvoltage and Monatomic Hydrogen." By W. D. BANCROFT.

"Depolarization by Electrical Waves." By W. D. BANCROFT.

"Electrode Surface Phenomena." By W. C. ARSEM.

"Contact Resistance of Metal Electrodes." By N. K. CHANEY.

"Contact Potentials and Electrochemical Potentials." By I. LANGMUIR.

1.45 P. M.—Steamboat leaves Washington for trip to Mount Vernon, returning by trolley car via Alexandria.

8.15 P. M.—Meeting in the Mezzanine Room, New Willard Hotel. The following papers will be read and discussed:

"Polarization in LeClanche Cells." By D. A. MACINNES.

"Electrolytic Formation of Perchlorate." By C. W. BENNETT and E. L. MACK.

"Unstable States in Arc and Glow." By W. G. CADY.

"Electric Arcs in Vapors and Gases at Low Pressures." By W. A. DARRAH.

"The Moore Tube for Color-Matching." By W. McF. MOORE.

"Corrosion and the Engineer." By W. H. WALKER.

"Effect of Rust Upon the Progress of Rust." By J. ASTON.

"Influence of Frequency of Current on Electrolytic Corrosion." By B. MCCOLLUM and G. H. AHLBORN.

Saturday, April 29, 1916; 9.45 A. M.—Meeting at the Bureau of Standards, Assembly Hall of the Electrical Building. The following papers will be read and discussed:

"Some Unsolved Problems of the Electroplater." By G. B. HOGABOOM.

"Nickel Plating." By F. C. MATHERS, E. H. STUART and E. G. STURDEVANT.

"Rapid Nickel Plating." By O. P. WATTS.

"Test of Tin Plating Baths." By F. C. MATHERS and B. W. COCKRUM.

"Use of Peptone in Tin Baths." By F. C. MATHERS.

"Addition Agents in Electrodepositing Silver from Silver Nitrate Solutions." By F. C. MATHERS and J. R. KNEBLER.

"Electrolytic Zinc." By W. R. INGALLS.

"Recent Progress in Electrolytic Irons." By O. W. STOREY.

1.30 P. M.—Luncheon will be served in the dining room of the Bureau of Standards.

Program of Meeting of American Chemical Society at the University of Illinois

The principal features of the program of the meeting of the American Chemical Society, to be held at the University of Illinois, Urbana-Champaign, Ill., from Tuesday to Friday, April 18 to 21, were given in our issue of April 1, page 358. Additional features are as follows:

The general session on the morning of Tuesday, April 18, 9.30 a. m. will be opened by speeches by Dr. W. A. NOYES, President EDMUND J. JAMES of University of Illinois, and President CHARLES H. HERTY of the American Chemical Society, whereupon the following addresses will be made:

L. H. SMITH, "The Composition of Corn as Affected by Nineteen Generations of Seed Selection."

ARTHUR H. THOMAS, "The Manufacture of Chemical Apparatus in the United States."

RAYMOND F. BACON, "The War and the American Chemical Industry."

G. H. A. CLOWES, "On the Influence Exerted by Electrolytes on the Equilibrium of Emulsions, Jellies, and Living Cells."

JOHN JOHNSTON, "Some Effects of High Pressure."

The same evening at 9 p. m., a "Get-Acquainted" Smoker will be held in the gymnasium annex.

On Wednesday, 2 p. m., the new Chemistry Building of the University of Illinois, will be dedicated, Governor EDWARD F. DUNNE of Illinois, presiding. Addresses will be made by President EDMUND J. JAMES of the University, Dr. ALEXANDER SMITH and Dr. W. R. WHITNEY.

In the evening of Wednesday a subscription dinner will be held at the Masonic Temple, Champaign.

Divisional meetings will be held on Wednesday, 9 a. m., Thursday, 9 a. m. and 2.30 p. m. Local excursions will take place on Tuesday and Thursday, 2 p. m., and the excursion to Danville on Friday, 7.30 a. m.

For Thursday evening, 8 p. m., two public lectures are scheduled by Dr. CHARLES L. PARSONS on the production of radium and by Dr. CURTIS F. BURNHAM on the use of radium in treatment of cancer.

An exhibition of chemical products and apparatus will be held in the basement of the new Chemistry



DIAGRAM OF EXHIBITS

Building. A floor plan of the exhibition is given in the adjoining diagram. The numbers in the sketch refer to the following exhibitors:

1. Scientific Materials Company; 2. METALLURGICAL & CHEMICAL ENGINEERING; 3. General Electric Company, Research Department; 4. Macbeth-Evans Glass Company; 5. Elmer & Amend; 6. Libbey Glass Company; 7. Standard Calorimeter Company; 8. Lenz & Naumann; 9. Duriron Castings Company; 10. Central Scientific Company; 11. Elyria Enameled Products Company; 12. U. S. Bottlers' Machinery Company; 13. Sweetland Filter Press Company; 14. National Lead Company; 15. Laboratory Supply Company; 16. National Carbon Company; 17. Sarco Company; 19. Mitchell Lime Company; 20. Emil E. Lungwitz; 21. Sowers Manufacturing Company; 22. Schaeffer & Budenberg Manufacturing Company; 23. Abbe Engineering Company; 24. Thwing Instrument Company; 25. Dearborn Chemical Company; 25. Edison Storage Battery Company; 26. John Wiley & Sons; 27. Henry Holt & Co.; 28. McGraw-Hill Book Company; 29. Longmans, Green & Co.; 30. P. Blakiston's Son & Co.; 31. Celluloid Zapon Company; 33. Thermal Syndicate; 34. E. R. Squibb & Sons, Mojonner Bros.; 35. Fairview Fluorspar & Lead Company; 35a. McIntosh Stereopticon Company; 35b. J. P. Devine Company; 36. Toch Bros.; 37. Braun Corporation; 38. Norton Company; 38a. Herold China & Pottery Company; 39. Pfaunder Company; 40. Permutit Company, Sharples Specialty Company; 40a. Armour Ammonia Works; 41. Schutte & Koerting Co.; 42. American Coal & Byproducts Company, Chattanooga Chemical Co.; 43. U. S. Metals Refining Company, Manhattan Rubber Co., Fato Co., Walrus Mfg. Co., and Leeds & Northrup Company in Research Laboratories, Physical Chemistry, Room 165.

The number of papers to be presented in the sessions of the different Divisions is little less than 300, as follows: Agricultural and Food Chemistry, 22 papers; Biological Chemistry, 76; Industrial Chemists and Chemical Engineers, 26; Organic Chemistry, 53; Water, Sewage and Sanitation, 28; Physical and Inorganic Chemistry, 62; Pharmaceutical Chemistry, 15 papers.

The chairman of the executive committee at Urbana-Champaign, is Prof. Edward Bartow.

Notes on Metallurgical and Chemical Engineering in Great Britain

(By our London Correspondent)

Industrial Coordination

In modern slang we are now going "all out" over co-ordination. There are governing bodies in Great Britain possessing powers of industrial control more absolute than anything conferred by medieval Parliament, and more dictatorial in their powers than any of the old trade guilds. The fiat goes forth to Messrs. So and So "you shall make such and such things," and Messrs. So and So conform. Again Messrs. Somebody-else inquire "may we execute this order for export, or that order for internal trade?" The reply "Yes" or "No" as the case may be is final.

This state of affairs has its philosophic interest no less than its future historic value or its immediate national purpose. We are out to overcome Prussianism. Your correspondent said in a previous letter that even in overcoming, success would leave us tinged with much that was Prussian. To-day he is tempted to go further and say that it is only in emulating Prussian co-ordination that we shall win through in a reasonable time. We are only repeating old precedents. The Christianity which overcame Paganism was overlaid with much that was Pagan. Again Paganism in putting forward Mithraism as its last word in those early centuries was consciously or unconsciously becoming the exponent of a monotheistic creed with distinct similarities to parts of the Christian doctrines. Lest any readers of this (after and if it has escaped the editorial blue pencil) wonder why your correspondent should soliloquize over his memories of the volumes about the decline and fall of another empire—volumes which he cannot get hold of at the moment—your correspondent can only plead keen interest which the abstract problems raise.

Among other things from which we have suffered has been that of a neglect of the historic sense. Otherwise we should never have had the spectacle of a British statesman declaiming in the House of Commons less than a decade ago that he did not believe that there were such things as inevitable wars. To-day it is not a very far cry from the orator in the Senate with his "Carthago delenda est" to a right honorable gentleman at Westminster observing that "he will stick at nothing" to win.

Well, in the co-ordination of industry—call it mobilization of industry if you will—we have out-Heroded Herod. We have done more in twelve months than the most pedantic Fabian would have conceived feasible in one hundred times as long in period. The miracle is that it works and works astonishingly well. Many people talk amiably banal stuff about going back to the old régime after peace comes. Of course, we shall not keep it up in its entirety, but we shall have given the doctrinaire Socialist most amazing precedents, and we shall have realized that national life is not a mere string of negative Commandments. The "Thou Shalts" will be more numerous than its "Thou Shalt Nots."

Of course, the trend of the future will have its bias toward bureaucratic control, but so long as the bureaucracy is honest and alert and intelligently virile, there are many worse conceptions than a capable bureaucracy.

Electrolytic Hypochlorites

It is now twenty years since your correspondent was in New York City and then concerned with the manufacture of hypochlorite of sodium from sea-water under A. E. Woolfe. Having subsequently been engaged in the manufacture and application of electrolytically produced solutions of hypochlorite to domestic disinfection,

sewage sterilization, and the bleaching of cellulose materials in England, it was of much interest to see in the *Times* the other day that the hospital ship Aquitania was fitted with an electrolyzer producing liquids of two grams of available chlorine per liter strength. The technical details are scanty in the extreme—apparently the cell has a large number of electrodes in series as it is used on a 110-volt circuit. To any one who knows what the germicidal value of one part per million of available chlorine in a drinking water or what from 5 to 8 parts per million will do in sterilizing sewage effluents, the enthusiastic praise of the medical staff of the Aquitania is no surprise.

Nothing is said in the newspaper accounts of the electrochemical efficiency or stability of the final product. The concentration in available chlorine is low, much lower indeed than that of Woolfe's solution which ran from 3½ to 5 grams of available chlorine per liter. Later in England the present writer found that stable solutions of 7 to 10 grams were commercially practical products, and that 12 to 15 grams solutions were practicable from the Crawford electrolyzer, but not commercial. It is rather a temptation now that one is middle-aged to review the last two decades of the electrolytic chlorine industry in England. On the one hand, we have the splendid financial success of the Castner Kellner process—against this there are other processes which yielded gaseous chlorine and sodium hydrate which have disappeared. There was, too, the meteoric career of the Commercial Development Company, with the patent litigation which wiped up the Rhodium cell.

Of the hypochlorites themselves their only field can lie in cases where the solution can be made and used on the spot. Otherwise their low concentration renders them economically impossible to transport. It is interesting to recall the types of cells one has known intimately—the Hermite, the Crawford, the Oxchloride, and the now moribund "Meridionizer." In all-round utility the Crawford was probably the best—but platinum anodes with platinum at present prices are unthinkable. Then we used to pay £4 per ounce—now, well it is doubtful whether at £30 per ounce anyone could secure enough platinum in Great Britain for cells having an aggregate input of say 25 kw.

Corrosion

Probably no more interesting discussion on corrosion has ever been held in England than that which took place at the Faraday Society at its meeting early in December. Sir ROBERT HADFIELD opened the proceedings by a communication on the "Corrosion of Steel Alloys." The world's iron losses by corrosion, he stated, in dwelling upon the importance of the subject, was estimated at hundreds of thousands of tons annually. Yet some Egyptian iron; e.g., a hatchet 2500 years old probably, discovered by Dr. Flinders Petrie in dry sand, he believed, was still apparently in its original condition. But nickel steels, supposed to be non-corrosive, rusted very badly when once corrosion set in, though high nickel steels were more resistant. He had lately again been engaged, together with Dr. N. Friend, in investigating the corrosion of special steels. Some chromium steels (about 11 per cent of Cr, 1 per cent of C), which he had made in 1892, were fairly non-corrosive, and still free from rust, and gave remarkable results in mechanical tests. Sir Robert had also analyzed and tested the "stainless steel for cutlery, and had made some himself, which contained from 10 to 12 per cent of Cr and about 0.3 or 0.4 per cent of C, while the commercial steels contained in addition 0.45 per cent of cobalt and little manganese and silicon; these steels had a remarkable hardness even before being hammered, and elongations

of up to 32.5 per cent. The material would probably require great care in forging and rolling, but an opening would, no doubt, be found for it."

Mr. LESLIE AITCHISON, M. Met., of Sheffield, described a further series of "Experiments on the Influence of Composition upon the Corrosion of Steel," dealing with pure iron and carbon steels and special steels containing tungsten, nickel, cobalt, manganese, chromium, vanadium, or copper. The special steels were studied in two series. In the one series the tungsten percentage rose from 2.36 to 26.3 (about 0.7 per cent of C), the vanadium from 0.7 to 12.45 (carbon 0.6 to 1.1 per cent), the cobalt from 2.68 to 20.85 (carbon again about 0.7 per cent), the chromium from 1 to 23.7 (0.85 per cent of C). In the second series both the fourth metal and the carbon varied, but the former only slightly, the tungsten steels containing about 3 per cent of W, the vanadium steels about 0.2 per cent of V, the chromium about 2 per cent of Cr, the nickel steels about 3 per cent of Ni, the manganese steels about 1 per cent of manganese, the copper steels from 0.45 to 4.78 per cent of Cu, however. In this last series the percentages of the third metal were not high as a rule, therefore, and the average percentage was selected on the strength of the previous experiments. All the specimens were immersed for many days (seventy-seven generally) in 3 per cent sodium chloride solution, in sulphuric acid of 1 per cent and of 10 per cent, and in tap water, the liquids being renewed seven times, and tested also microscopically.

The main conclusions drawn from the many experiments were the following: In the case of carbon steels the corrosion decreased with the increase of carbon, having a minimum at 0.35 per cent C, and then rose again. The addition of a third metal in small amounts almost always increased the corrosion, though the results were not regular, nor always concordant; tungsten conferred no gain at all; vanadium was useful only in tap water; cobalt corrosion up to 11 per cent; manganese steels were very irregular; chromium had some remarkable effects. No steel was found sufficiently homogeneous to resist corrosion; even the most homogeneous bar iron (0.07 per cent of C) contained amorphous intergranular cement, and there were strains and twined crystals in all the steels. Yet non-homogeneity was not in itself productive of easy corrosion, for a 19.46 per cent chromium steel (0.85 per cent of C) was not attacked at all in salt solution, though composed of an intimate mixture of carbides and solid solution. The true secret of non-corrodibility seemed to lie in some property—possibly low solution pressure—of the solid solution; the solution pressure of iron was not low. Carbides themselves were not attacked; but they acted as acids, providing cathodes, and the pearlite in them promoted attack, though the pearlite might not itself be attacked; the attack seemed to affect rather the ferrite and the solid solution, which formed the matrix for the carbide. Corroded metals containing free carbide were generally found to be corroded with loose carbide particles; but bigger carbide grains would remain embedded in the solid solution, and the boundaries of the grain were similarly fixed.

Papers were also read by Dr. J. N. FRIEND, and by Mr. S. WHYTE and Mr. PENDRED. The latter gentleman mentioned that he had, three years ago, started experiments, in conjunction with Mr. Harbord, on a rather large scale, taking plates of all sorts of iron and steel, 12 in. square, up to $\frac{3}{8}$ in. thick, and exposing them in London air (which proved worse than salt water), tunnel air, Thames water (which did little harm), acids, exhaust steam, etc. The result was that specimens of the same steel might behave very differently, but that on the whole nothing could be said as to the superiority.

Papers were then presented dealing with the non-ferrous metals—these I propose to summarize in my next letter.

University and Industry

Meeting of New York Section of American Chemical Society

The third of the series of meetings of the New York Section of the American Chemical Society for the purpose of discussing co-operation between the universities and industries was held at the Chemists' Club on Friday evening, April 8, 1916. The chairman, Dr. T. B. Wagner presided. At this meeting the side of the industries was presented by Dr. Wm. H. Nichols and four debaters discussed the question. The two former meetings on November 12, and December 10, were devoted to Columbia University and the Massachusetts Institute of Technology (see this journal Vol. XIII, pp. 885 and 941, Dec. 1 and 15, 1915). This last meeting was well attended and the talks were very interesting and many valuable suggestions were made which should do a great deal toward furthering a closer contact between our universities and industries.

Before the regular program of the evening a bill which is before Congress to compel the use of the Centigrade scale in government publications was read by Colonel Wadsworth. If passed this will mean the ultimate elimination of the Fahrenheit scale in government publications. Colonel Wadsworth urged the society to support the bill. Another bill called the Newland bill which is before Congress was explained by Dr. Willis R. Whitney. This bill provides for the establishment of a department to be known as an engineering or mechanic acts experiment station in every state in the Union. Dr. Whitney said the essence of the bill was that it put research on a business basis in certain colleges in each State. A stipulation of \$15,000 per annum for each State is also provided.

The section was fortunate in having the president of the society, Prof. CHARLES H. HERTY, present, who made a few remarks before the regular program. President Herty spoke of the value of local sections in affecting national thought. He dwelt particularly on the dyestuff problem and paid a splendid tribute to the New York Section for its speedy action in the fall of 1914 in taking up the dyestuff problem and recommending duty rates which should be placed on imports of dyestuffs. He said that recently a convention of Southern cotton manufacturers, almost all Democrats and in a fully Democratic section of the country, had enthusiastically endorsed these rates by a unanimous vote and that they had sent notice of this endorsement to Congress. He also said that local sections could meet more quickly than a national body in cases like the one just cited, and that therein lay their inherent value.

The first speaker on the regular program of the evening was Dr. WILLIAM A. NICHOLS, chairman of the board of the General Chemical Co. Dr. Nichols presented a very valuable address in which he discussed all phases of the problem and made an important announcement which will be quoted further on. He explained that the subject of co-ordination of the university with the industry began very early with him, in fact practically as soon as he graduated from college. He has always followed the technical chemical line and has never failed to avail himself of the valuable assistance of the university professors, consequently he was much in sympathy with the general subject of co-operation between university and industry.

A chemical engineer is more hampered in the making than other engineers because he has not enough prece-

dent to go by. So much of the chemical work done is never published and consequently he labors under a severe handicap. Summer work is a great benefit to his education.

But after all is said and done it is the individual professor rather than the university whose co-operation is needed, and while it is highly desirable that a professor have the advantages which a large institution can confer, nevertheless the fact should not be lost sight of that in many cases the best person will be found in a smaller institution. Dr. Nichols referred to Professor Walker's criticism of the industries in not taking the professors into their entire confidence so that the fullest measure of co-operation could be obtained. Dr. Nichols said the criticism was true and that it was foolish of the industries not to do so. He agreed with Dr. Little's remark that the student should leave the university with a definite purpose in view, and that he should have a fairly good command of English. He deplored the shortcomings of the average technical student in these respects.

Purely theoretical chemistry and applied chemistry are but different phases of the same subject. It is impossible to work out pure theory without benefiting some one. Our industries rest upon the foundations laid by pure chemistry. Let each have its place and let the best co-operation between the two exist.

In visiting Berlin and Vienna some years ago in the interests of the Eighth International Congress of Applied Chemistry, Dr. Nichols said he was deeply impressed with the great interest taken by government officials in the chemical industries. In England, previous to the war, the government took no interest in the chemical industries. Dr. M. O. Forster labored many years trying to bring about such a co-operation. The recently established British Dyes, Ltd., is the first attempt at anything in this line.

The Japanese Government in 1915 passed a bill granting subsidies for ten years to those who would take up the manufacture of chemicals or medicines. The subsidy was to take the form of a guarantee to provide sufficient funds to allow dividends of 8 per cent to be paid on all capital invested for a period of ten years.

Our Oriental friends have gone much farther in government co-operation than we have. The universities and industries should co-operate but if they are the only factors that co-operate we won't get far. If the Universities could turn out some international law makers who would become so imbued with right ideas that they placed patriotism above party, great benefits would result. The universities have always wanted to do their share. The industries are beginning to line up more and more to let them help.

In this latter connection Dr. Nichols outlined a plan formulated by his company for effecting co-operation. "Briefly stated," said Dr. Nichols, "my plan is as follows: We are forming what we call an 'Advisory Council' composed of great chemists in their several lines, located in various universities and schools of science. Each member of the council will receive a modest honorarium, and be expected to attend meetings occasionally at which specific problems will be discussed, as well as any other subject of interest to any of the members. In order that the co-operation may be as complete as possible, I hope to attend these meetings myself, and to have the highly valuable assistance of two or three of the best of our staff.

"Naturally, as the meetings will only be occasional, correspondence between the head office and the members of the council, and between the members themselves, will be frequent. New problems will be referred to the council, and by it referred to the member best qualified

to solve it. The report, if favorable, will after discussion, be passed along to the research department of the company, which in turn, if thought advisable, will bring it before the engineering staff.

"Starting with a small number the council will elect its own members, subject only to the approval of the officials of the company.

The next speaker was Dr. MARSTON T. BOGERT, of Columbia University who said that we must not think of a university as a business enterprise. In fact universities are run at a loss. The chemical industries on the other hand are run purely for making money and have no philanthropic motives. In the dissemination of knowledge there is little co-operation between universities and industries. Our text books are far behind actual practice and a great deal of useless repetition of work is carried on through the lack of publicity given to much of our industrial chemical knowledge. A university chemical department should not perform experiments for a company with the sole idea in view of divulging the information to that company only. Thereby the university laboratory becomes merely a works laboratory. If the universities withdraw from pure research there is little likelihood of its being done anywhere else. Pure science and applied science should work side by side. Industrial research fellowships in university laboratories bring good results.

Dr. Bogert referred to the success of the Mellon Institute in Pittsburgh. He said that at the present time they have over forty fellowships, with appropriations of \$130,000 for same and an additional \$50,000 to \$60,000 required for bonuses. The institute has had to refuse to accept any more work, being so crowded. The Kaiser Wilhelm Institute in Germany which is a splendid example of the pure research institution is supported largely by the manufacturers.

Dr. Bogert made the suggestion that New York City should have an institute of chemical research which could render a great service both to the manufacturer and to the university laboratory.

The next speaker was Mr. E. H. HOOKER, president of the Hooker Electrochemical Co. Mr. Hooker spoke in appreciation of Dr. Nichols' plan for co-operation and said he thought it was the broadest thing yet suggested. He offered the criticism that his company usually had to train chemists to be engineers or to train engineers to be chemists. It is hard for one to get the viewpoint of the other. Mr. Hooker laid great stress on the human factor, as contrasted with the orderly process. He said they found great trouble in getting the chemist to adopt the human factor. He said young graduates should enter their profession with humility, and pointed out several requisites which he considered essential. The first essential is a trained mind. What the industries need is technical graduates of broader culture. A good general education preceding the technical studies is invaluable. English, economics, public speaking—these are too often overlooked. There is nothing equal to Latin and Greek for widening the vocabulary. Single-mindedness and tenacity of purpose are further desirable qualifications.

Mr. Hooker said that the obligations of the industries to the universities is very great and it should be a pleasure to help them. The "tricks of the trade," however, are vital and are of inestimable value. They are the results of long years of experience and are not likely to be disclosed. He spoke of the value of such institutions as the Research Corporation.

The next speaker was Dr. P. A. LEVENE of the Rockefeller Institute. Dr. Levene said that in all true history, science was always following the economic needs of a country. The first science was astronomy. This with

mathematics developed at a time when society was dependent principally on trade. Biology developed with the further advance of agriculture. If science has always followed the needs of industry is there any necessity of compulsion to form agreements by which science may be made to serve the industries? There are two functions of chemical science in the development of the industries. First, the development of new theories which lead to new industries. Second, the chemistry of immediate demands. The universities and industries should be completely divorced and immediate industrial problems should not be worked out in the university laboratory. There, only pure chemistry should reign supreme.

The next paper was presented by Dr. BENJAMIN L. MURRAY of Merck & Co. Dr. Murray was strongly in favor of the idea of extension teaching. Almost every university feels the need of more funds. The promotion of funds and a more intimate contact are the two vital questions. Among the ways of developing contact there are the fellowship idea, intermittent training of the student, including a year or summer spent in the works. The teachers should also go into the industries occasionally. Special lectures at the schools by men from the industries are valuable. Why not have the teachers address the industries also?

A few remarks were then made by Dr. H. P. TALBOT, of Massachusetts Institute of Technology, who enlarged upon the idea of extension teaching and said if one could see the earnestness with which night school pupils go into the work it would be an inspiration.

Dr. JOKICHI TAKAMINE then gave a very interesting little talk on the establishment of chemical manufactures in Japan, alluded to by Dr. Nichols. Dr. Takamine, in commenting upon the enthusiasm of the Japanese people said that when the granting of subsidies was announced, a certain company was started with a capital of 8,000,000 yen (1 yen = about 50 cents). The stock was to be offered for public subscription, and in ordering stock it was necessary to deposit $2\frac{1}{2}$ per cent of the face value in a bank. He said that this $2\frac{1}{2}$ per cent alone which came in, amounted to 17,000,000 yen. Upon a recent trip to Japan, Dr. Takamine said he had advocated the establishment in Japan of a chemical and physical institute with an appropriation of 10,000,000 yen. A committee of fifteen leaders of industry, and fifteen chemists and scientific men was appointed. They have been working hard trying to establish the institute. About two weeks ago a bill was passed in the Japanese Parliament granting 2,000,000 yen for its support, and the Emperor has given 1,000,000 yen from his private fortune, so that the institute is really under way and the balance will be raised from manufacturers.

A few closing remarks were made by the chairman, in which he stated that some final conclusions would be drawn up from all that had been said on co-operation and would be presented at a later meeting. The meeting was then adjourned.

Society of Chemical Industry Meeting

The next meeting of the New York Section of the Society of Chemical Industry will be held in Rumford Hall, Chemists' Club, Friday evening, April 21. The following interesting program has been provided.

"The Application of Centrifugal Force to Emulsions and Suspensions," by EUGENE E. AYRES, JR., of the Sharples Specialty Company.

"The Present Status of the American By-Product Coke Oven Industry," by T. C. CLARKE, consulting engineer.

"The Volumetric Determination of Tin—A Review," by R. L. HALLETT, National Lead Company.

The Western Metallurgical Field

Flotation at Cripple Creek

Indications point to the treatment of a rapidly increasing tonnage of Cripple Creek ores by flotation. The Portland company is already handling several hundred tons per day at the Independence mill, which, when completely remodeled for the new process, will have a capacity of 1000 tons daily. In addition to this, the company has officially announced that its other Victor mill, which was erected several years ago for the cyanidation of low-grade ores, is to be remodeled for flotation with a capacity of 1000 tons daily. When these changes are in effect, this one company alone will be treating 2000 tons per day by flotation, using the Callow air-cell.

The Vindicator will be the second large company to enter the flotation field on a large scale. The first unit, designated as a testing unit, will be erected immediately, and will be based on the results and experience obtained from months of testing on a scale of ten tons per day. The ultimate capacity of the Vindicator flotation plant will be in the neighborhood of 1000 tons per day, but the first unit will treat but 300 tons per day. Run-of-mine ore is to be washed before crushing for flotation. This washing process will produce a high-grade shipping product and will be beneficial to the subsequent flotation by removing oxidized portions of the ore that do not give a good recovery by flotation. The agitation-froth process probably will be installed and thus afford an interesting comparison with the air-bubble process at the Portland mills.

Flotation concentrates from these mills probably will be treated at the valley plants at Colorado City, where high-grade Cripple Creek ores are now cyanided after roasting, or they may be shipped to valley smelters. The gradual abandonment of cyaniding in favor of flotation is an index of the manner in which the latter process may affect metallurgical conditions by offering economic advantages. The practice of cyanidation in the Cripple Creek district was a metallurgical achievement that deserved all the prominence it received. Profits were taken from ore that previously had been waste, and the companies performed a true service of conservation. That successful processes may now be abandoned, reflects only the short life of methods in these days of rapid progress.

Lead Companies Advance Wages.

It has long been customary in certain Western States to base wages for employees in the copper-mining industry on the market price of the metal, increases or decreases being automatic. In the lead industry, however, conditions have not been so favorable until recently, when the market price took a decided rise. Recognizing the justice of an increased wage, lead producers in the Coeur d'Alene district of Idaho have announced a schedule of bonuses to apply automatically when lead is above 5 cents per pound. When lead is at $5\frac{1}{4}$ cents, wages are to be increased 25 cents per shift; at $5\frac{1}{2}$ cents, the increase is 50 cents per shift, and above 6 cents the bonus is 75 cents. In February the price was such that the 50-cent bonus was paid, while for March and April a 75-cent bonus will apply. About 6000 men are affected by this change, and the estimated increase will amount to about \$100,000 per month under present conditions.

Coal Refining in Colorado.

Many of the Western States contain tremendous quantities of lignite coal, aggregating several hun-

dred billion tons, according to the disclosures made by the Bureau of Mines, the United States Geological Survey and the State surveys. The use of these lignites as fuel in the raw state is a wasteful process, owing to their peculiar physical condition and chemical composition. In order to conserve the true value of these coals, some kind of preliminary treatment is necessary. They contain valuable volatile products, which distill at low temperatures and do not even yield their full fuel value when burned in the ordinary furnace. On the other hand, they may be distilled in closed retorts, their distillates condensed and separated, and the carbonized residue briquetted with a binder and used as fuel. Under such treatment the condensed volatile products may become of chief importance, with briquets as a by-product.

Colorado lignite is being refined in this way by the American Coal Refining Co. which has a plant at Denver. The coal is crushed to 1 in. and minus, and distilled at a low temperature in ovens of special construction, 36 ft. long, 9 ft. high and 18 in. wide. These retorts are heated by a part of the gas derived from distillation, the combustion taking place in flues in the oven walls. The time of distillation is two hours, and the weight of the charge in each retort ten tons. Temperature is raised gradually to 500 deg. C., resulting in the distillation of gas, ammonia and tar. The last is an important material, from which other products are obtained by subsequent fractional distillation.

By reason of the low temperature at which the coal is carbonized, the distilled products are different from those obtained from high-temperature treatment. The tar especially varies from that obtained at high temperatures, containing more light oil and creosote and less pitch. When this tar is distilled, it yields at 150 deg. C. from 10 per cent to 14 per cent of light oil; between 150 deg. and 325 deg. C. about 68 per cent of creosote, with a final residue of pitch containing but little free carbon. The creosote product is advocated as a suitable oil for flotation work.

The carbonized residue from the first distillation of the coal is mixed with a binder and briquetted. Following are analyses and fuel values of the raw coal and briquets.

	Lignite	Briquets
Moisture	12.0%	1.35%
Volatile matter	29.0	7.60
Fixed carbon	55.0	84.05
Ash	4.0	7.00
Fuel value	9,900 B.t.u.	14,400 B.t.u.

Flotation at Cobalt

Developments at Cobalt, Canada, indicate that flotation will prove an important factor in the concentration of local ores. At the mill of the Dominion Reduction Co. a 5-ton experimental unit is in operation, handling the product of one of the stamps. The Nipissing company has had a 20-ton experimental unit in operation for some time, treating cyanide tailings from the low-grade mill. The largest installation is that of the Buffalo, which is using the Callow process. The ultimate capacity will be 600 tons per day, and when the plant is in operation it will displace slime concentrating tables. The equipment consists of eight roughing and eight cleaner cells, together with the necessary accessory apparatus. At the McKinley-Darragh mill preparation is being made for the use of two rougher and two cleaner cells, which will provide a capacity of 150 tons per day.

Progress at Anaconda

From the current issue of *The Anode* we note that considerable progress has been made in construction

work. The reconstruction of the concentrator has been completed, and the remodeled portions are now in commission. The oil flotation department is in full operation; the No. 2 roaster is practically complete, and one-third of the furnaces are in service. The large reverberatory furnace, which has been under construction at the converter plant for the purpose of retreating converter slag, is also complete and in service. The construction of the last two of the Great Falls type of converter is now well under way. The addition to the zinc plant is also nearing completion and will probably be in operation during the present month. At Great Falls the grading for the electrolytic zinc plant has been completed, and concrete foundations are being poured.

Company Reports

The annual report of the Hometake Mining Co. for the year 1915 shows that 1,573,822 tons of ore was milled, realizing an average of \$4.08 per ton. Bullion receipts amounted to \$6,428,787, which with other income and balance brought forward gave a total receipt of \$7,423,379. Dividends amounted to \$2,210,208. The balance carried to profit and loss account at the close of year was \$1,032,933. Notable among the disbursements other than operating expenses are items of \$13,671 for the aid fund, \$2,800 for benefices, \$50,249 for hospital and \$12,078 for operation of the recreation hall.

The prosperity of the zinc industry is reflected in the annual report of the American Zinc, Lead and Smelting Co. for 1915. The company has an outstanding capital stock of \$4,828,000. The total profits from operations, after deducting cost of mining, manufacture, marketing, administration, taxes and interest, amounted to \$5,135,056. Appropriation to depreciation and reserve fund was \$2,642,378. The balance carried to surplus was \$2,651,500. At the beginning of the year the company had notes payable amounting to \$1,130,000 and a bonded debt of \$549,000. The notes have been paid and the bonds converted into stock, par for par. A net deficit in quick assets of \$643,452 was converted into a net surplus of quick assets of \$3,668,706. The following additions to property were made during the year: Purchase of the Roseberry mine at Mascot, Tenn., and erection of a 700-ton mill; increase of capacity of No. 1 mill at Mascot from 1200 tons per day to 2200 tons; options on property in vicinity of Mascot; construction of one block of furnaces, one new kiln and addition to acid department at Hillsboro; one kiln and block of furnaces at Dearing; two kilns and four blocks of furnaces at Caney. The Wisconsin Zinc Co. added valuable leases and built a modern roasting and magnetic separating plant.

The eleventh annual report of the Nipissing Mines Co. for 1915 shows a production of 4,097,391 fine ounces silver, at a cost of 19.06 cents per ounce. The gross value was \$2,222,256, and the net receipts \$1,441,427. Shareholders received \$1,200,000. Ore reserves contain about 9,000,000 ounces silver. At the high-grade mill the only change made during the year was an improvement in retorting amalgam, which is now retorted and melted to bullion in one heat in large graphite crucibles in tilting furnaces. The average grade of Nipissing ore treated at the high-grade mill was 2474 oz. silver per ton. Custom ore averaged 2917 oz. per ton. The market for cobalt residue was poor on account of the war, and only 326 tons were shipped. The low-grade mill treated 77,071 dry tons of ore assaying 29.62 oz. silver per ton. The extraction was 87.52 per cent. Stamp duty was 6.57 tons per day. Notwithstanding an increase of 20 cents

per ton in cost of supplies, the total cost of treatment was reduced 7 cents per ton. The Callow screens, which had been used in the tube-mill circuits, collected metallics containing 176,158 oz. of silver, but as extraction was not improved or cost reduced by this procedure, it was discontinued. Experiments are under way to provide a method of precipitation to supersede aluminium dust, as that product has become too expensive to warrant continuing the present method. It is probable that the solutions will be precipitated with sodium sulphide, the resulting silver sulphide being desulphurized by aluminium ingots in caustic soda solution. Tests with flotation have indicated the possibility of making a small additional saving from tailings, and a four-cell unit is in operation. The cost of milling, including transportation and sorting, based on milling 77,183 tons, was \$3.91 per ton. Supplies cost as follows, per ton of ore treated: sodium cyanide, 95.6 cents; lime, 1.98 cents; caustic soda, 7.85 cents; aluminium dust, 27.84 cents; pebbles, 4.66 cents; power, 74.76 cents.

The Iron and Steel Market

The steel market has grown still stronger, accomplishing something that appeared almost impossible. The extremely sharp advances made by the large mills during February and March, amounting to an average of \$10 a net ton on finished steel products generally, except standard rails, might have been construed as representing a desire on their part to bring about conditions whereby they would be able to participate in the higher prices being secured by the smaller mills on a number of products for early shipment. In bars and plates in particular the small mills were securing very high prices for prompt shipment, and as everything is unprecedented in this steel market there was an opportunity to infer that the large mills were ready to renounce forward sales and work themselves into the position of being able to make early deliveries at the fancy prices going for such delivery. There would, then, be a decrease in the volume of business placed so that the mills would begin catching up.

Results have not been in keeping with any such expectation. The Steel Corporation's statement of unfilled obligations at the close of March, made public March 10, is 9,331,001 tons, representing an increase of 762,035 tons. There was heavy buying of rails in March, for 1917 delivery, and assuming that rail obligations increased 400,000 tons there was left, for other products, an increase of 350,000 tons, which with shipments of at least 1,250,000 tons in the month indicates bookings apart from rails of no less than 1,600,000 tons. Yet at the beginning of March steel prices for forward delivery were \$7 a ton higher than on January 1 and by the same amount higher than the level attained in 1907, the highest in fourteen years. Thus at exceptionally high prices the bookings exceed the shipments and the time when they are to fall short of shipments is still in the future. The corporation's capacity is now fully 1,250,000 tons a month, so that the business on books at the end of March, if suitably distributed, would carry the corporation to the middle of November. How long the mills will continue to operate at capacity is a very indefinite problem, seeing that bookings still exceed shipments. When they begin to fall behind there will still be business drifting in that will operate to prolong the period of great activity. It is the usual experience that the mills operate at capacity for a longer time after the edge comes off the market than is generally expected. Such was distinctly the case in 1913.

Despite repeated predictions that orders for war steel

would diminish, the inquiry is still insistent and the volume that actually reaches the market seems to be controlled by the possibilities of the business being placed more than by any predetermination of requirements on the part of buyers.

The embargo on the New Haven system is practically lifted, and the Pennsylvania is being relieved by the transfer of cars which for months have been congesting its tracks in the East. A freer movement of steel to the East, including New England, is beginning, promising a more pronounced scarcity of steel in the Central West. Early last December, when shipments from the Pittsburgh and more Western districts to the East began to be held up, there were fears that steel production would thereby be curtailed or other consumers would be offered too much steel. Nothing of the sort occurred and now the influence in the opposite direction is likely to be quite noticeable.

While the steel makers are naturally interested in so interesting a steel market, their greatest concern at the present time is with respect to the labor situation. Week by week labor has been growing scarcer, and the paying of premium wages has become common in the steel making industry. The influences of the general opening of outdoor work on roads and general construction work and of the great call for farm help, are still to be felt, and are greatly feared. From the time the war started to March 1 the increase in population of the United States due to persons entering the country, less those leaving, is 1,050,000 less than would have been the case if the movement had continued of the average volume shown in the two years preceding July 1, 1914. At such a time, with the iron and steel industry and its coke branch so in need of this particular class of labor, and with conditions growing worse steadily, Congress turns its attention to the passage of an immigration bill with a literacy test advertised to be framed for the purpose of restricting immigration.

Pig Iron

In a generally interesting iron and steel situation the pig iron position is of particular interest. While pig iron has advanced an average of \$6 a ton on this movement, which began in pig iron the middle of last year, or six months later than the advance started in finished steel products, the advance in both unfinished and finished steel is fully \$25 a ton. That is one element in the situation. Another is that the blast furnaces have proved their ability to make much more pig iron than was assumed. A rate of 40,000,000 tons a year has been reached, when a year ago it was doubted whether the industry could materially exceed 35,000,000 tons, and it was thought that if the demand for steel should outrun capacity the blast furnaces rather than the steel works would constitute the throttling point. A third is that consumers generally have in the past few months been so alive to the possibilities of a pig iron runaway that they have covered quite fully, in most instances, to the end of the year, and thus there is at the moment a distinctly quiet market. Finally, there are distinct prospects of the large steel interests requiring much more pig iron than they can make themselves, and of their entering the merchant furnace market. There is a possibility, too, that furnaces will fall behind in deliveries. It is understood that the United States Steel Corporation and the Republic Iron & Steel Company have sold much less than their normal proportions of Southern iron, with the intention either of shipping Southern basic iron to their Northern steel plants or of holding the iron to match sales of it with purchases of iron in the North. We quote: No. 2 foundry, delivered Philadelphia, \$20.25 to \$20.75; f.o.b.

furnace, Buffalo, \$19 to \$19.50; delivered Cleveland, \$19; f.o.b. furnace, Chicago, \$19; f.o.b. Birmingham, \$15 to \$15.50; f.o.b. valley furnaces, 95c. higher delivered Pittsburgh; Bessemer, \$21 to \$21.50; basic, malleable and foundry, \$18.50 to \$19; forge, \$18 to \$18.50.

Ferromanganese is \$175 on contract, but is practically nominal at that figure, offered deliveries to the end of the year being well taken up, with some business closed for the first half of next year. Most of the large steel interests are carrying three or four months' supply in addition to what will become due them on contract. Prompt lots have been bringing \$400 and higher on the few occasions in which any becomes available.

Steel

For months there has appeared reason to believe that with constantly advancing prices a point would be reached at which mills would have some tonnages of soft steel to offer, but the time does not arrive. There are practically no mill offerings at any price, and even the middlemen have practically nothing. If market prices are to be quoted they can be reached only by a combination of uncertain inferences, at, say, \$45 for Bessemer and \$45 to \$50 for open-hearth, for either billets or sheet bars, but these quotations are practically nominal. They appear to be the figures that are least likely to be regarded as either too high or too low. Steel rejected under war specifications is bringing \$40 and higher, although the buyers as a rule are getting material far from that which they would pick out. If the high carbon is not objectionable the high manganese is undesirable. Sulphur and phosphorus are, of course, much lower than the average buyer requires. Size seems to be the principal determining point. Stock lists of rejected steel with single items sometimes involving thousands of pounds rather than tons or carloads are eagerly scrutinized. Ordinary forging billets are \$65 minimum, while war steel billets are \$75 and higher. Ordinary rods are nominally about \$60, with high carbon rods bringing \$75 to \$85.

Fixation of Atmospheric Nitrogen Before Congress

The House of Representatives, by a vote of 224 to 179, has stricken out section 82 of the military bill, containing an appropriation for the Alabama Power Co.'s Muscle Shoals project. But the fight for this is going on.

On March 31 Senator Oscar W. Underwood in a remarkable speech (*Congressional Record*, Vol. 53, No. 86, page 6016) discussed the atmospheric nitrogen fixation problem from the preparedness viewpoint. On account of limitations of space we can only say that it was an unusually able speech from a technical standpoint. Senator Underwood favors the cyanamid project rather than the Du Pont project (mentioned in our issue of April 1, page 362). He accused several advocates of the latter project of lobbying. They have since replied and denied the charge. Senator Underwood introduced the following amendment:

That to provide for the fixation of atmospheric nitrogen, by improvement of navigation and development of water power, necessary for the manufacture of nitric acid in times of war and fertilizers in times of peace, the Board of Engineers for Rivers and Harbors, subject to the approval of the Secretary of War, is hereby authorized and directed, first, to hold hearings and conduct negotiations for the purpose of determining upon a suitable air nitrogen process and the terms under which it can be made available, and second to select a suitable site on a navigable stream in the United States for the construction of the necessary dam, locks, substructure, power house and hydroelectric equipment. The Board shall report its findings, with estimates of cost, to the Congress at the earliest practicable time, accompanied by recommendations as to what plans should be adopted for providing the government an assured and adequate supply of nitric acid in times of war, and, consistent with this purpose, for effectively and economically serving to the greatest extent practicable the agricultural interests of the country in the manufacture of fertilizers in times of peace.

Mr. Frank S. Washburn, president of the American Cyanamid Company, has issued for private circulation a very ably written pamphlet entitled "THE FACTS IN THE NITROGEN CASE NOW BEFORE CONGRESS," which contains a great deal of very interesting information. In part, some of the information is new, having not been divulged to the public before in print.

From the technical standpoint perhaps the most interesting part of the pamphlet is the appendix which we herewith give in full:

"More or less uniform opinion has been expressed as to the relative characteristics of the two principal processes for the fixation of atmospheric nitrogen, known as the 'arc process' and the 'cyanamid process,' respectively. The arc process proceeds on the simple fact that at the high sensible temperature of the electric arc nitrogen and oxygen combine chemically to form a nitrous gas which when taken into aqueous solution becomes weak nitric acid. The cyanamid process is based on the simple fact that a carbid, such as calcium carbid, when in a finely subdivided state will, under high temperature, combine chemically with nitrogen gas to form a cyanamid. This can be easily converted to ammonia by the addition of steam and ammonia gas by a contact process can be oxidized to weak nitric acid.

"The arc process requires for the fixation of a unit of nitrogen between five and six times as much power as is required by the cyanamid process. For the production of 180,000 net tons of concentrated nitric acid per annum 540,000 continuous horsepower is required by the arc process and 100,000 continuous horsepower by the cyanamid process, which at \$100 per horsepower installation cost is the difference between \$54,000,000 and \$10,000,000.

"The total installation cost of the arc process is excessive compared with the installation cost of the cyanamid process, particularly where the cost of developing power is not extremely low. With the cost of power installation at the moderate American figure of \$100 per continuous horsepower on the switchboard a plant of 180,000 net tons of concentrated nitric acid per annum by the arc process would cost \$80,000,000 and under the same conditions a plant of the same capacity by the cyanamid process would cost \$20,000,000. For the production of fertilizers alone the disproportionate cost of plants of equal capacity is much greater than indicated by the figures above for the production of nitric acid.

"Concentrated nitric acid by the arc process, taking the installation cost of power of \$60 per continuous horsepower on the switchboard, costs per ton to produce one-third more than by the cyanamid process. This disproportion is, of course, correspondingly greater where the cost of power installation is \$100 per continuous horsepower. The disproportion in the cost of producing equivalent quantities of nitrogen in the form of fertilizer alone is greater than for nitric acid. Even with power at what would be an abnormally low figure in the United States, namely, a \$10 operative cost per continuous horsepower on the switchboard, the pound of nitrogen produced by the arc process costs for power alone as much as the total cost of the pound of nitrogen by the cyanamid process, including power, materials, labor, interest, amortization and depreciation.

"The world production of nitrogen by the way of the arc process is equal to 32,000 net tons and by the way of the cyanamid process to 200,000 tons per annum. It is interesting to note that the world production of nitrogen by the arc process is only two and one-half times the productive capacity of the single plant of the American Cyanamid Company at Niagara Falls, Canada.

"The arc process, except as to some minor unsuccessful attempts, has been confined to Norway whereas the cyanamid process has found application in Norway, Sweden, Germany, Austria, Italy, France, Japan and Canada.

"Persons of late have seen fit to throw doubt upon the commercial practicability of the cyanamid process for the production of nitric acid because of the lack of experience in this country in the oxidation of ammonia, which is one of the steps in the production of nitric acid by cyanamid. There are a number of processes for the oxidation of ammonia. The particular process in the development of which the American Cyanamid Company collaborated has application in Germany equivalent to the production of 120,000 tons of concentrated nitric acid per annum. The art is so well established in Germany that the details are now subjects of discussion in the technical periodicals,* and

*In this connection the article on page 425 of this issue, based on a recent article in *Metal and Eng.*, will be found of particular interest.—Editor MET. & CHEM. EN'G'G.

an issue of the *Chemiker Zeitung*, so late as December, 1915, contains a discussion of the subject, setting forth the results guaranteed by the projectors of two of the processes. In this connection their guaranteed efficiencies vary from 90 per cent to 95 per cent. It should therefore be quite clear, without accepting the mere statement of interested parties, that the process has attained practical perfection in the only respect in which for a time it was deficient, namely, as to chemical efficiency. An English company is establishing cyanamid nitric acid plants throughout the allied countries of Europe and guaranteeing 90 per cent efficiency. The costs of production are substantially 70 per cent of what it costs to manufacture nitric acid by the way of Chilean nitrate. The art was quite new when the European war began and the enormous demand throughout Europe for nitric acid has given it an extraordinary impetus and brought about refinements in efficiency and in the cost of production which otherwise might have taken years to accomplish."

In the pamphlet itself, Mr. Washburn discusses after some introductory remarks first "the military demand" for nitrogen, due to the fact that all military explosives are made from and by the use of nitric acid and that nitric acid can only be secured in practicable quantities from nitrate of soda from Chile or by the fixation of atmospheric nitrogen.

"Germany had available within her borders at the outbreak of the war 660,000 tons of nitrate of soda. She imported from Chile during 1914 up to the outbreak of the war on Aug. 1 in excess of 800,000 tons and it is estimated that she captured at Antwerp another 200,000 tons. All of this supply was consumed during the early months of the war, during which period Germany expanded on an enormous scale the air nitrogen industry, already well established in that country. To this end she expended substantially \$100,000,000, employing an additional 300,000 continuous horsepower. Even the Allies, to whom the road to Chile is completely open, are employing 500,000 continuous horsepower in the fixation of atmospheric nitrogen in the form of explosive materials and are actively engaged in the establishment of nitric acid factories by the way of the cyanamid process throughout their various countries."

Mr. Washburn then takes up the economic demand for nitrogen. Man's chief concern is food. Food prices rose 80 per cent in this country from 1896 to 1912. Limiting the price of food is largely a question of lowering the cost of its production. Cheaper production is only compatible with an increased crop return per acre cultivated without increased expenditure of human labor. If this be true of European countries with 50 cents per day field labor how much more important is it to this country with two dollars a day labor.

In 1907 Germany had 43,000,000 acres sowed to wheat, barley, rye, oats and potatoes, and harvested therefrom 3,000,000,000 bushels, while from 85,000,000 acres sowed to the same crops in the United States, American farmers harvested only 1,875,000,000. From less than one-half the area German farmers harvested double the number of bushels. Why this extraordinary difference? The answer lies chiefly in the fact that Germany uses seven times as much fertilizer as the United States to the average acre cultivated. Is it surprising that during the period in which the cost of food rose in the United States 80 per cent it rose in Germany only one-half as much?

For the needs of the American farmer the American Cyanamid Co., by extensive research work, has developed a universal fertilizer, a cheap ammonium phosphate in which the nitrogen content is a secondary product of the cyanamid process, while the phosphoric acid is extracted from phosphate rock by a new process.

The principal factors that any comprehensive nitrogen plan should possess are formulated by Mr. Washburn as follows:

"For National Defense.—The plant should provide in time of war not less than 180,000 tons of nitric acid per annum; it should to the extent of 25 per cent to 50 per cent of the ultimate capacity be in readiness for operation within eighteen months; it should place upon the country the least

burden and therefore the minimum taxation for its support; it should add to the country's facilities for production and not merely divert existing materials from established uses.

"For Agricultural Advancement.—The plant should provide a sufficient quantity for universal use of cheaply produced, highly concentrated complete fertilizer.

"Various Federal legislative plans have been suggested for meeting the national military and economic problem presented by our nitrogen requirements. With the preceding facts in mind one is prepared to pass judgment upon their general sufficiency to cope with the situation.

"Du Pont Project.—The E. I. du Pont de Nemours and Company are credited with offering a solution for the nitrogen problem. This, we believe, is a misconception of the du Pont purpose, although late communications addressed to the Secretary of War and to certain Senators, as well as newspaper interviews attributed to their representatives, seem to indicate a confusion in the minds of the du Pont officials of their company's exact place in the nitrogen situation. The du Pont Company has announced that \$20,000,000 is available for the establishment within the borders of the United States of a nitric acid plant, providing an acceptable water power site with the requisite permit can be secured. From the late official statements of du Pont representatives this expenditure would be sufficient to complete at the end of four years the development of 120,000 hydroelectric horsepower and the construction of a nitric acid plant with all its appurtenances capable of manufacturing 40,000 tons of nitric acid per annum. They state that it is not their purpose to produce any fertilizer. The Birkeland-Eyde Arc Process for fixing atmospheric nitrogen in the form of nitric acid is to be used, the American rights to which were secured by the du Pont Company about two years ago.

"The du Pont Company are large producers of powder in the manufacture of which they use considerable quantities of nitric acid, approximately in normal times 40,000 tons per annum, made from Chilean nitrates at a cost (as to a part thereof) greater than that at which it can be produced with cheap water power by the arc process. They plan to have in readiness at the end of four years a plant for furnishing for their own use a quantity of nitric acid equivalent to about 20 per cent of the anticipated minimum this Government would require in the event of war. There is no intention of manufacturing fertilizer, nor any possibility of doing so, except in practically infinitesimal quantities and of a kind inappropriate for general use under American conditions. Were the plant proposed by the du Pont Company ready to manufacture to-day at full capacity instead of four years from now, the present nitrogen situation would be altered only to the extent of having a source of nitric acid supply within the country equivalent to approximately 20 per cent of the probable war demand and available only at the sacrifice of mining and quarry operations, as necessary in war times as in peace, by taking from them their necessary blasting powder.

"Cyanamid Project.—The author of this paper was asked by the War Department about six months ago to recommend to the Government means by which it could have an assured ample supply of nitric acid in event of war. The general idea so far as it had been developed by the War Department was to build a Government plant of war time capacity to stand idle for the most part during peace times when the Government's use for nitric acid is inconsiderable. Rather exhaustive studies were made and the resulting estimates along the lines projected by the Department were placed before it, covering two quite different processes, the cyanamid and the arc, the first involving an expenditure for the full plant of approximately \$30,000,000 and the second, not including the requisites for shipping the product, approximately \$70,000,000.

"The questionable operative practicability of such a plan, the great useless standing investment through long years of peace and the very grave doubt as to Congress appropriating so large a sum for so unusual a purpose were sufficient incentives to developing a plan under which there would be no operative risks, only on inconsiderable idle investment and no additional expenditure on the part of the Government except for the development of the requisite water power at such site as the Government might select, and the repayment to the Government by the lessee of 3 per cent per annum on the cost thereof. The plan in detail, as explained to various Congressional committees upon their invitation, is as follows:

"First.—The Government is to develop 100,000 primary hydroelectric horsepower at any place which will serve the military and commercial purposes to which the power is to be applied. This would call for an installation of 125,000 to 130,000 hp. capacity measured on the switchboard, which, taken at an assumed installation cost of \$100 per horse-

power, would amount to \$12,500,000 to \$13,000,000. The Government is to own the entire plant.

"Second.—Private capital is expected to construct at an estimated cost of \$23,000,000, including working capital, a fertilizer plant, rent the requisite hydroelectric power for its operation from the Government and pay 3 per cent on the Government's investment for developing the same, together with the cost of operating the power house. The fertilizer plant is to produce a high grade, concentrated universal fertilizer equivalent in plant food constituents to 2,200,000 tons of standard 2-8-2 fertilizer goods.

"Third.—Private capital is to install at an estimated cost of \$1,000,000 the buildings and special appliances necessary to introduce a subsidiary process, exclusive of the fertilizer processes, by which 20,000 tons of nitric acid per annum would be produced for the Government's peace time requirements.

"Fourth.—The Government is to install at an estimated cost of \$5,000,000 the buildings and special appliances necessary to introduce a subsidiary process, exclusive of the fertilizer processes, by which the plant will stand in absolute readiness to produce 90,000 tons of nitric acid per annum and have all the buildings and everything, except easily procurable articles of merchandise, in store on the premises necessary to complete the plant within three months for an additional 90,000 tons.

"Fifth.—The Government is to have nitric acid at all times in such quantities as it may desire at the cost to the manufacturer for furnishing it plus such additional amount as profit as the Secretary of War in his judgment may determine from time to time as reasonable.

"Sixth.—Provisions are to be made against exorbitant or discriminatory prices being charged for the fertilizer produced under this plan.

"Seventh.—Provisions are to be included by which 45,000 to 90,000 tons nitric acid capacity shall be in readiness within eighteen months at moderate increased expenditure if any at all."

Mr. Washburn then discusses the production of ammonia from by-product coke-ovens. He concludes that the production of coke-oven ammonia from year to year varies greatly and depends on the fluctuations of the iron industry; that the ammonia produced at present from by-product coke-ovens is completely consumed in industries from which it could hardly be withdrawn, without great damage, in case of war (37 per cent of the total coke-oven ammonia is used in cold-storage, 10 per cent in explosives and chemicals and the balance in fertilizers). Moreover nitric acid from coke-oven ammonia would cost considerably more than nitric acid secured by way of the fixation of atmospheric nitrogen.

"Germany, the greatest European country in metallurgical industry, producing 90 per cent of her coke supply in by-products plants, turned to atmospheric nitrogen for her war requirements.

"One of the fundamental principles of the [by-product coke oven] industry is that the natural place for the by-product coke oven is in the hands of the large producers of iron, such as the United States Steel Corporation, as an added economy in the production of their principal product. There are a number of operative demands in connection with the handling of the by-product oven which place limitations upon the extent to which it can be profitably employed. The requisite combination of favorable conditions is rather uncommon and it is a mistake to assume that the by-product coke oven is universally practicable, and that its future growth is to be measured in direct ratio to the future coke consumption of the country. One of the serious limitations upon the growth of the by-product coke oven is the relatively great investment involved therein. Notwithstanding these facts some enthusiasts have suggested that coke ovens could be erected wholesale for the purpose of supplying ammonia for the making of nitric acid in times of war. In order to supply by this means the amount of ammonia required in the manufacture of 180,000 net tons of concentrated nitric acid per annum an investment of \$100,000,000 would be required in coke oven plants alone and it would require coking about 27,000,000 tons of coal per annum, or 75,000 tons per working day. In conclusion upon this subject it may be said that to depend upon ammonia liquor from by-product coke ovens would have the vital defect of not subscribing to the first principle of preparedness, which is to add something to the country's protective capacity in order to meet war conditions rather than to subtract from it."

Mr. Washburn then takes up briefly one proposed method of government ownership and operation and finally discusses the possibilities of development by private capital as follows:

"Nitrogen in time of peace is consumed in the form of fertilizer alone to an extent seven times as great as in the form of nitric acid. The increased war time demand for nitric acid is enormous. No private interest can afford to prepare itself to manufacture nitric acid to meet war demands for the reason that it would have, over years of peace, idle investment upon which there would be no return.

Cheap water power is the chief requisite in the fixation of atmospheric nitrogen. The United States is not a country of cheap water powers. It is quite the contrary. The disproportion as to the annual cost of the continuous hydroelectric horsepower, as shown in the great mass of testimony before various committees in Congress, is from three to six dollars in Norway to twelve to twenty dollars in the United States.

No private interest engaged in the fixation of atmospheric nitrogen seeking the greatest commercial advantage would locate its factories in the United States, nor if so located would it equip itself to produce more than a very moderate amount of nitric acid. The markets of the United States can be best filled from plants located at the cheap Canadian water powers. The only means by which hydroelectric power can be cheaply enough furnished to the fixer of atmospheric nitrogen at any practicable manufacturing sites in the United States is through the Government making the investment for power and renting it to the user by charging the low rate of interest at which the Government can borrow money.

Furthermore, industries of the nature of the fixation of atmospheric nitrogen are new to American investors and where the cost of developing the necessary power constitutes, as it frequently would in the United States, one-half of the total investment, to be relieved of making the investment for power brings the amount which must be raised by private investment within such an amount as will meet the limitations of the American investor.

The nature of the author's interest and his purpose in presenting a nitrogen plan for the consideration of the Government has been misunderstood by certain senators and representatives. The following facts may serve to correct any misunderstanding:

1. The American Cyanamid Company is representative of one of the four industries which must have an extraordinary amount of extremely cheap water power, the others being the carbide industry, the aluminum industry and the arc process. The Union Carbide Company is the sole representative in the United States of the carbide industry and it has secured water powers in Norway for future developments. The Aluminum Company of America, the sole representative of the aluminum industry in the United States, is confined to the use of those powers which are within range of the necessary raw materials, and this company has had the advantage of being early in the field in its demand for power and has secured the cream of the large cheap powers in the United States. The arc process has not so far found its way outside of Norway except in an experimental way. The du Pont Company states that it was their purpose to establish the arc process in Canada. The Cyanamid Company is in Canada and has laid its plans for remaining there. These facts alone should be sufficient to establish in the public mind what is definite knowledge to those engaged in large electric furnace operations, namely, that such industries must for their commercial success seek sites for manufacturing in those countries where ample, cheap hydroelectric power can be developed.

2. The American Cyanamid Company is engaged in extensive developments for the purpose of providing for the use of the farmers of this country a great supply of a concentrated chemical compound of nitrogen and phosphoric acid, constituting a fertilizer of superior merit in all respects.

3. The American Cyanamid Company has made no proposal or advances of any sort to the United States Government. It has not asked for nor does it desire Government aid or assistance.

4. The fact of the author's interest in water-power development and past association with particular water-power sites has no relationship of any kind whatsoever to the nitrogen problem or the plan he has suggested for solving it.

5. The author has done his best in compliance with an unsought invitation from the War Department to suggest a plan which he believes would be of extraordinary national benefit and practicable of accomplishment.



The New Chemical Laboratory of the University of Illinois

History of the Chemical Department at Urbana-Champaign—Description of New Chemical Laboratory

The dedication of the new Chemical Laboratory of the University of Illinois at Urbana-Champaign will take place on Wednesday, April 19, 1916. It will be a great event in the history of the University of Illinois: Governor Edward J. Dunne of Illinois, will preside, and addresses will be made by President Edmund J. James, Dr. W. R. Whitney, and Dr. Alexander Smith. The importance of the event for the future of chemistry in America will be appropriately indicated by the fact that the American Chemical Society will hold its fifty-second general meeting in connection with the dedication exercises.

A historical review of chemistry at Urbana-Champaign in the past is particularly fitting at the present time. It has been written with a full personal knowledge of the facts and with the loving heart of the historian in unison with his subject, by Prof. S. W. PARR who has been connected with the University of Illinois since 1890. It is published in the "University of Illinois Bulletin" 25. From Professor Parr's article the following sketch is extracted. While it is restricted to the most important facts, we hope it will be found interesting enough to encourage our readers to look up and read Professor Parr's article in full in the "Bulletin."

* * *

The opening of the University of Illinois occurred on March 11, 1868, and in the first annual report of the Regent (President) it was said to be "especially important that an appropriation should be made to fit up, at once, a chemical laboratory."

In the autumn of 1868, A. P. STUART, of Lawrence Scientific School, Harvard University, was elected as

the first professor of chemistry at a salary of \$2,000 a year. The initial cost for equipping the laboratory was \$978. The following plan of compensation for chemicals used by the students was evolved by Professor Stuart:

"For a course of two hours daily, excepting Saturday, during a term of twelve weeks the sum of \$12 shall be deposited by each student. For a course occupying four hours daily the sum deposited shall be \$24, and for a course of six hours the sum deposited shall be \$36. An account shall be kept by the Professor of Chemistry with each student; all articles shall be charged to him at cost and a credit entered for all articles returned in good condition, except that a charge of 20 per cent of the cost shall be made for the use of same. Such percentage, however, shall not exceed \$3 for the term. Students pay the cost value of the apparatus broken or destroyed by them individually. . . . All money received from students for chemicals and apparatus shall constitute a distinct fund from which the Professor of Chemistry may draw to purchase supplies from time to time as occasion may require."

In 1869 the Legislature appropriated \$5,000 and with the revenue thus provided the first laboratory was equipped and operated. It was located in the basement of the south wing of the original University Building. The equipment of the laboratory was materially increased as a result of a trip to Europe by Professor Stuart during the summer of 1871 for the purpose of selecting in person the apparatus desired. Among the list of accessories was a platinum retort for making hydrofluoric acid, weighing 1000 grams and costing \$200. (It was exchanged in 1903 for about \$800 worth of much needed platinum dishes.) Professor Stuart paid careful attention to the proper selection of chemical journals and reference books for the library. Under what difficulties he had to run the laboratory is evident from the

facts that the only water available was from the college pump, that there was no city gas supply, and, of course, electricity by the meter route was unknown. A kitchen stove was installed in the laboratory and this was the only source of heat. When no appropriation for a new laboratory was forthcoming, Professor Stuart resigned at the end of the year 1873-4.

"Whether it may be taken as an index of the low cost of living or the economical propensities of the professor is not stated, but it used to be remarked about the campus that he came at a salary of \$2,000 per year, stayed five years and took away \$10,000 with which to start a banking business in the West. However, he was unmarried, and lived in the building in a sort of supervisory capacity."

HENRY A. WEBER was Stuart's successor and M. A. SCOVELL was elected in 1876 assistant professor of chemistry, in charge of agricultural chemistry. An appropriation for the new chemical laboratory was secured early in 1877 and amounted to \$40,000. City gas became available and water under pressure was provided from a large steel tank supported in the mansard story and kept supplied by a pump in the basement. An unfortunate disagreement with the Board in 1882 resulted in the withdrawal of Professors Weber and Scovell.

Professor WILLIAM McMURTRIE was appointed head of the department in September, 1882. The position of professor of agricultural chemistry was not revived. Dr. A. W. Palmer served as First Assistant in Chemistry. When Professor McMurtrie resigned in 1888 to become chief chemist for the Royal Baking Powder Company, Dr. Palmer also resigned. Dr. J. C. JACKSON became professor of chemistry, but his reign was short-lived. Dr. A. W. PALMER was recalled from Europe in 1889 and shortly afterwards was made a full professor.

"It should be noted that at this time a new life and altogether different aspect of affairs were in evidence at the University. The most potent factors were doubtless the change in name from the 'Industrial' University to the 'University of Illinois' in 1885, and the increased revenue from the action of the federal government in the Hatch Act of 1887 and later in the Morrill Land-College Aid Act of 1890. These two measures were to augment the revenues at the outset by over \$30,000 annually. This was a relatively large sum since the total state appropriation for the year 1889-90 was only \$31,750 of which \$16,000 was designated as for 'expenses and instruction.' The total state appropriation for the biennium 1889-91 was \$59,000."

In December 1890 SAMUEL WILSON PRATT was appointed to the chair of analytical chemistry, but in 1894 it was decided that his title be changed to that of professor of applied chemistry and that Dr. Palmer's and Dr. Pratt's departments "be separately organized as agreed upon between themselves."

The Chemical Club was organized in 1892.

The Illinois State Water Survey was organized in 1895 under Dr. Palmer's direction with C. V. MILLAR as "assistant in chemistry in the State Water Survey."

In the spring term of 1899 the honorary chemical fraternity, Phi Lambda Upsilon, now grown to national status, was organized.

In the early morning of Aug. 5, 1896, the laboratory was struck by lightning, and very considerable damage was done.

In 1901 an appropriation of \$100,000 was secured for the Chemistry Building. This amount was less than half of what the department considered essential. The question to be decided, therefore, was whether to build one-half of the laboratory and equip the same for work, or to plan a building which would take care of the increase in students for the coming twenty-five years, but

with very little in the way of equipment. If the first plan were followed it was absolutely certain that a second large appropriation would have to be asked for within ten years, and the outlook for such a procedure was altogether discouraging. The other plan, therefore, was followed with the result that when the contract was let for the building there was only \$800 left for equipment. This was sufficient to place four new desks in the quantitative laboratory and supply a few hoods. Every desk in the old building was moved over. Many of these were marred from the effects of the fire and all were battle-scarred from twenty years of strenuous use. It certainly was a distressing feature in making the new building ready for occupancy in the fall of 1902 to see these old wrecks hoisted by rope and tackle to the third story and skidded into place for service again with the Freshmen. Fortunately at the next session of the Legislature, in 1903, an item of \$20,000 was allowed under the designation of "material and equipment for the chemical laboratory." This item was repeated in the budget for a number of succeeding sessions and very materially relieved the situation. At least the departments were able to keep fairly abreast of the rapid increase in the number of students.

On Feb. 2, 1904, occurred the death of Professor Palmer. He had been ill but a short time. The direction of the State Water Survey had brought on a tremendous amount of work and responsibility, especially in connection with the survey of the Illinois River before and after the opening of the Chicago Sanitary Canal. His second report covering the work from 1897 to 1902 and embodying the results of the Illinois River and Sanitary District Survey is a monument to his untiring industry and ability. He literally gave his life in the service of the University and the State.

Dr. H. S. GRINDLEY, who had been appointed Assistant Professor of Chemistry in 1895, and Associate Professor in 1900, continued in charge of that department for the remainder of the year.

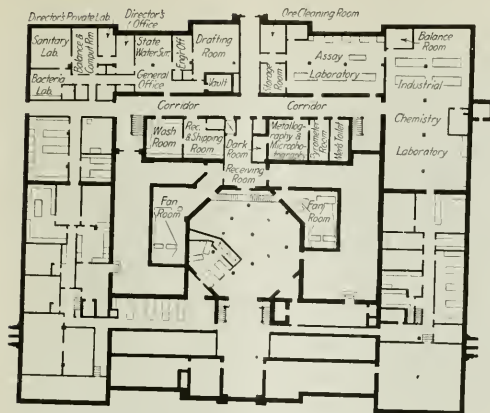
At the meeting of the Board for August, 1904, the following recommendation by the President was passed:

"(1) That the Department of Applied Chemistry be discontinued as such and that there be one Department of Chemistry. (2) That Professor Parr's title be continued as that of Professor of Applied Chemistry and Associate Professor Grindley be made Professor of General Chemistry. (3) That the headship of the department be divided so that Professor Parr shall have general charge of all matters pertaining to instructors and instruction, and Professor Grindley as Director of Laboratory shall have charge of and be responsible for all business and material affairs. They will then so adjust matters that each shall have supervision over definite subordinates and courses of instruction, and each be directly responsible for the men and work so assigned."

From September, 1904, therefore, the consolidation of the two departments was effected and the work carried on as above ordered until the appointment of Dr. W. A. NOYES as "Professor of Chemistry and Director of the Laboratory" beginning Sept. 1, 1907. At the same time Dr. Grindley was appointed chief in Animal Chemistry in the Agricultural Experiment Station and Professor of Animal Chemistry in the College of Agriculture. The State Water Survey was put under the supervision of Professor Parr in February, 1904, and so continued until the appointment of Professor EDWARD BARTOW, Sept. 1, 1905.

The Illinois section of the American Chemical Society was organized April 24, 1906, with twenty-six members. At the present time there are 152 members of the section and all but thirty-seven are connected with the University.

In April, 1908, the Zeta Chapter of the National Chemical Fraternity, Alpha Chi Sigma, was installed.



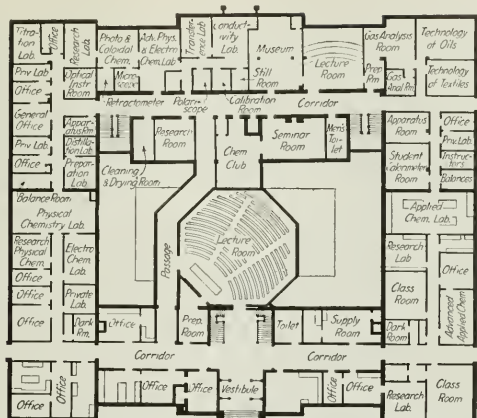
GROUND FLOOR—STATE WATER SURVEY, INDUSTRIAL CHEMISTRY, VENTILATION SYSTEM

The new building entered in 1902 soon became crowded to such an extent that distress signals were in evidence even when only one-half of the estimated time of twenty-five years had passed in which it was assumed there would be ample room. Instead, the need for an addition to the building was urged upon the legislative session for 1913. The addition to the University fund from the mill tax, available after July 1, 1913, made it possible to proceed with the plans for the new addition and the contract was let Aug. 14, 1914.

It is of interest to note that the number of students specializing in chemistry has grown from 14 in 1872 to 245 in 1915, of whom 75 are in the graduate division.

Description of the Laboratory

The building erected in 1901-2 as a home for the Department of Chemistry resembled the letter "E" in shape, the extreme dimensions being 230 ft. along the front and 116 ft. along the wings. This building contained 77,884 sq. ft. of usable space, which it was estimated would provide ample room for the needs of the department for at least twenty-five years. The growth has been so rapid that in 1914 work was begun upon an addition which has a larger capacity than the original building. The cost of the addition is more than double that of the original building. The completed building

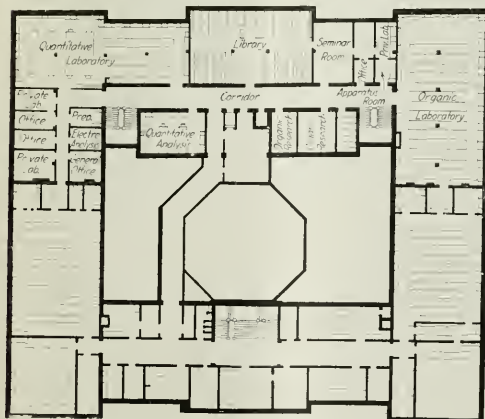


FIRST FLOOR—PHYSICAL AND INDUSTRIAL CHEMISTRY

is in the form of a hollow square, 231 ft. by 202 ft., containing 164,282 sq. ft. of working space. The center is occupied by the main lecture room, which is lighted by a skylight; two large ventilator fans are housed in the court, which arrangement prevents annoyance from noise and vibration.

The old portion of the building is not fireproof, but is divided into three sections by fire walls, while the new part is built of fireproof material. The floors are a combination of reinforced concrete joists and hollow tile, the concrete covering the tile to a depth of 2 in. Upon the concrete the electrical conduits are laid and these are covered with a top layer of concrete, rubbed to a smooth surface. The top surface consists of a layer of "rezilite mastic," about $\frac{1}{8}$ in. in thickness. This is a preparation of elaterite, containing some asbestos fiber, which gives elasticity to the floor, and is superior to asphalt because it does not yield under the pressure of heavy furniture. The floors in the halls have the terrazzo finish.

The roof is constructed of concrete slabs which are covered with wood sheeting, building paper and slate. The purpose of the wood sheeting is to give an air space for insulation purposes and to furnish a better means of laying the slate. Being entirely covered on



SECOND FLOOR—QUANTITATIVE ORGANIC CHEMISTRY



THIRD FLOOR—GENERAL CHEMISTRY, QUALITATIVE ANALYSIS, BACTERIOLOGY (TEMPORARY QUARTERS)



FOURTH FLOOR—GENERAL AND PHYSIOLOGICAL CHEMISTRY, ATTIC, HYDROGEN SULPHIDE, DISTILLED WATER

all sides by fireproof material, the sheeting does not increase the fire risk.

The minor partitions are made of "pyrobar" tile. A brick wall separates the old and the new portions of the building, making it possible to completely shut off either side. There is almost no wood used in the new part, the largest amount being for doors and window frames. A majority of the rooms are finished with a wooden base board, chair rail, hang rail and picture molding.

Abundant hood space is provided in all parts of the building. The hood construction used throughout the building consists of the following: The top is a single frame of plate glass with wire reinforcement, so set as to avoid as far as possible the gathering of dust; the linings are white tile; the doors are counterpoised, the weights being attached by means of a creosoted hemp rope. The pulleys and axles are made of wood. Each hood is connected with a flue which runs to the top of the building independently of other hoods. Ventilation is by forced draft.

In the larger laboratories the air is brought in at the corners of the room, and distributed at various openings along the ceiling, while the foul air is formed out through the hood flues. In this way there is an even distribution of the fresh air in all parts of the room, and the air is changed six times per hour.



LABORATORY OF ORGANIC CHEMISTRY,
UNIVERSITY OF ILLINOIS

In the laboratories for elementary chemistry there are upon the student desks special ventilation conduits which are connected with exhaust fans capable of changing the air in these laboratories eleven times per hour. These conduits rise a few inches above the level of the table top, so that the gases are drawn downward and discharged into a large flue. The toilet rooms are provided with special exhaust fans giving a very thorough ventilation.

The window sills in the halls and offices are of white marble, and those in the laboratories are of alberene stone, which material is also used generally for shelves and table tops. All tables are supplied with gas, water, waste and suction; some also have blast, high-pressure steam, distilled water and hydrogen sulphide. The building is completely wired with five electric systems: 10, 110 and 220-volt direct current and 110 and 220-volt alternating current. Many laboratories are also connected with the storage battery system. In the attic a large water distillation apparatus is placed as well as a hydrogen sulphide generator. The hydrogen sulphide is stored in a 500-gal. gas tank, which permits the distribution of the gas to various parts of the building under constant pressure.

Besides the main lecture room, which seats 390, the equipment includes one smaller lecture room, seven recitation rooms, four seminar rooms, a library, a museum and a room for the Chemical Club. Fireproof vaults and an elevator are available from all floors.

The general plan of space distribution is to have most of the offices, the library and the research laboratories in the new part with the routine laboratories in the old; the office of the director and the general executive offices of the department are in the old portion of the building near the main entrance of the west front. The large stock room and the ventilation equipment are also in the old part. There are five entire floors available for laboratory purposes in the new addition. Individual desks are provided for 1280 students in general chemistry and qualitative analysis, 400 in quantitative analysis, and 192 in organic chemistry.

Centrally located, on the second floor of the new addition, there is an exceptionally well-equipped departmental library.

In an adjoining seminar room is the Palmer Memorial Library, containing the private collection of chemical works and journals of the late Dr. Arthur W. Palmer.

The Department of Chemistry contains the following divisions: Divisions of Inorganic and Analytical Chemistry, Division of Physical Chemistry, Division of Organic Chemistry, Division of Physiological Chemistry, Division of Sanitary Chemistry (which is intimately connected with the Illinois State Water Survey), and the Division of Industrial Chemistry.

The *Illinois Chemist* is a quarterly magazine published in the interests of the faculty, alumni, and students of the Department of Chemistry of the University of Illinois, under the auspices of the University of Illinois section of the American Chemical Society, the Chemical Club, the Alpha Chapter of Phi Lambda Upsilon and the Zeta Chapter of Alpha Chi Sigma.

The alumni of the Department of Chemistry of the University of Illinois number 397.

For the first semester 1915-16 there are 75 graduate students; further in the department of chemical engineering 11 seniors, 23 juniors, 34 sophomores, 32 freshmen; in the department of chemistry, 13 seniors, 15 juniors, 18 sophomores, and 13 freshmen. There are 10 general science students with chemistry as major course, and other students taking chemistry number 1901. Thus the total for the first semester 1915-16 is 2145.

Production of Nitric Acid from Ammonia by the Ostwald Process

The production of nitric acid from ammonia has become very important during the past year in Germany and is attracting now also considerable attention in this country (see, for instance, papers by W. S. Landis, this journal, Jan. 15, 1916, page 87, and March 1, 1916, page 260). The process by which ammonia is changed into nitric acid is usually called the Ostwald process, but in reality there are a number of such processes, all depending on the same principle and differing only in the design of apparatus and kind of catalyzer employed. We will retain the designation "Ostwald process" for the sake of brevity.

The Ostwald process was described in considerable detail in this journal, Vol. XI, page 438, 1913 (compare also Vol. XI, page 476, 1913). Some further interesting data on this process and its use in connection with the lead chamber process of making sulphuric acid are given in an article by G. Schüpphaus, in *Metall und Erz*, Vol. XIII, page 21, 1916.

When the imports of saltpeter were shut off by the war it was very important that Germany find other means of making nitric acid, not only to be used as such, but also for the manufacture of sulphuric acid. Most of the sulphuric acid made in Germany is made by the lead chamber process, in which nitric acid is necessary.

Up to the beginning of the war there was no process for the manufacture of nitric acid without the use of natural saltpeter which had found any considerable practical use in Germany. The fixation of atmospheric nitrogen by the electric arc had been limited to localities where cheap electrical power was obtainable and the oxidation of ammoniacal nitrogen by the aid of catalyzers (Ostwald process) was not used to any extent. With the latter reaction it was possible in the shortest time to develop a series of practical processes which all depend on the same principle but differ in the apparatus and nature of catalyzer. One of these processes

(Frank and Caro) was devised to be used in connection with the lead chamber process of making sulphuric acid. The apparatus is made by the Berlin-Anhaltische Maschinenbau A. G. in Berlin.

Impure ammonia liquor is first purified and then pure ammonia gas from this liquor is conducted to the catalyzer apparatus, where it is mixed with air and passed over the heated catalyzer forming nitric oxide and steam. From here it is conducted to the lead chamber.

In purifying the ammonia liquor it is first run into agitating tanks and as much milk of lime added as is necessary for the decomposition of combined ammonia. It is diluted until it contains 2 to 3 per cent ammonia, then pumped to the top of a separating column where the ammonia is gasified by steam. The ammonia-steam mixture is conducted from the top of the separating column to two water-cooled condensers, the liquid in the separator flowing to the bottom. From the condensers (which condense the water only) the ammonia gas goes to two soda washers containing soda lye solution of 30 deg. Baumé, which frees it from hydrogen sulphide, phenol, and other impurities which might affect the platinum gauze catalyzer further on. From the soda washers the pure gas is led to a gas container, which equalizes the varying gas pressure. From the container it is ready to be conducted to the catalyzing element. The operation of the pump which pumps the liquor to the separating column is arranged so that the gas container is always kept half full of gas.

The pure ammonia gas is now conducted to the element shown in detail in Fig. 1, and in the installation of three elements in Figs. 2 and 3. The usual method is to use three of these elements as a unit, running two of them at a time and saving the third for reserve, for a lead chamber system of 10,000 tons (metric) of 60 deg. acid annual production.

At the bottom as shown in Fig. 1, the ammonia gas enters on one side and air on the other. The air and ammonia before they meet each other and mix, pass through gage collars as indicated, whose diameters are so selected that a proper mixture of air and ammonia for burning will be obtained. For further adjustment a valve is placed in each line. The air and ammonia are mixed by a rotating aluminium plate, and pass then through a narrow iron wire screen.

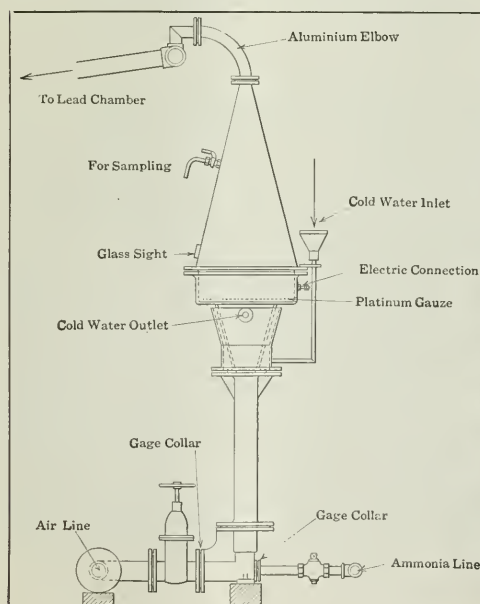
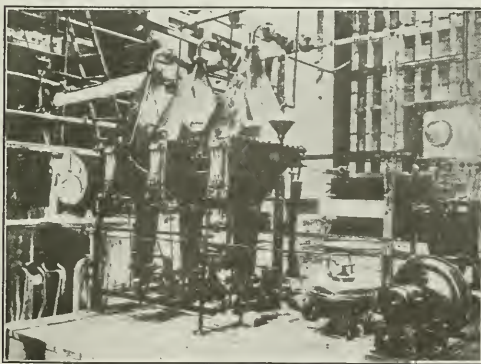
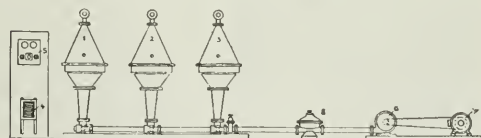


FIG. 1—SIDE VIEW OF CATALYZING APPARATUS



FIGS. 2 AND 3—UNIT OF THREE HEATING ELEMENTS

The air-ammonia mixture now goes to the platinum gauze, which is heated to about 700 deg. by electricity. At this temperature an almost quantitative conversion of the ammonia to nitric oxide and water takes place. The platinum gauze takes about 120 to 150 amp., at 24 to 26 volts for heating. In order to prevent as much as possible, breaking up of the ammonia by radiation and conduction from the glowing platinum gauze, before it reaches the hot zone, the lower half of the casing surrounding the gauze is cooled by water. For conducting away the oxide of nitrogen an iron hood is fastened to the burning chamber. This hood rapidly diminishes in cross section, and is lined with sheet aluminium on the inside, in order to prevent iron oxide particles from falling down on the platinum gauze. The elbow leading from the iron hood is also of aluminium.

The process is simpler if instead of impure ammonia liquor, pure sal-ammoniac containing about 25 per cent NH_3 is available. The lime tank, soda washer, etc. are then unnecessary and only the separating column need be used with two condensers and a gas container, also the frequent obstruction of the separating apparatus by lime does not occur.

The sal-ammoniac is best conducted to the separating apparatus in the following manner (Fig. 4). The sal-

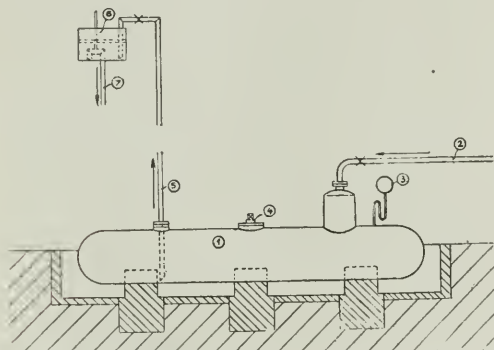


FIG. 4—METHOD OF DELIVERING SAL-AMMONIAC SOLUTION TO GASIFYING APPARATUS

ammoniac solution as needed is raised from tank 1 by means of compressed air into a small container 6 which has a connection 7 with the separating apparatus. In order to prevent evaporation of this solution as much as possible, a layer of oil is run in on top of the liquor and the tube 7 has a joint in the container as shown to prevent the oil from flowing into the separating apparatus. To break any syphon an open tube leads up from the joint as shown. The apparatus is very easily taken care of when pure sal-ammoniac is used and no special labor is required. A valve is supplied by the Berlin-Anhaltische Maschinenbau A. G. which automatically regulates the flow of ammonia solution, so that any attendance is unnecessary. The valve is regulated by the amount of gas in the container.

Once in a while the separating apparatus will become clogged up by iron oxide or hydroxide. This necessarily stops the flow of oxide of nitrogen to the lead chamber. On this account it is best to have a reserve apparatus.

The separating apparatus has a daily capacity (24 hours) of 5 cubic meters of liquid. If 2.5 per cent ammonia is in impure ammonia liquor water is used this means 125 kg. of ammonia gas; if 25 per cent ammonia is used as in sal-ammoniac it means that 1250 kg. ammonia gas per day may be generated, hence the desirability of using the latter.

The heating element should be placed before the head wall of the head chamber in the sulphuric acid plant. With this arrangement the formation of condensate in the 9 meter nitric oxide line is, however, not prevented in spite of good insulation. This condensate attacks the iron tube strongly and frequently causes shut downs. On this account the gas should be conducted to the head chamber in the shortest possible way. Stone pipe was adopted which projected in the chamber about 0.25 meter.

During the first trials, frequent interruptions occurred and at every interruption the chamber gases flowed back through the apparatus, passed the platinum gauze and escaped through the air ventilator. Through the contact with the chamber gases the platinum was rendered temporarily useless as a catalyzer. It was necessary to treat it with hot hydrochloric acid before re-using. This back flow was prevented by placing an iron plate trap in the main conducting line which is kept open when the flow is toward the chamber but closes when the flow starts to reverse.

Some of the nitric acid gas may be diverted from the main conducting line and condensed for use as a reserve in case of shut downs.

The Nitrate Industry in Chile

In a paper presented before the Second Pan-American Congress in Washington, D. C. (January, 1916), Enrique Cuevas gave a review of the status of the nitrate industry.

Caliche, the raw material from which the nitrate of commerce is extracted, was discovered in the great desert of northern Chile by the Indians some time in the seventeenth century. The first nitrate company was organized in 1812 with very crude reduction methods employed. The present era in the industry dates from 1855 with the introduction of steam as a means of heating and evaporating the solutions.

In 1873 the Peruvian Government assumed a monopoly of the nitrate lands and made grants in a careless manner. This led to much difficulty encountered by Chile when that country was left in possession of this area at the close of the Pacific war. However, titles have since been generally cleared up and beneficial laws enacted, covering not only the matter of land disposal, but of labor and other important questions.

According to the latest official report of the inspector general of the nitrate deposits, the zone of nitrate-bearing ground comprises 200,000 square kilometers, of which less than 3 per cent has been surveyed and prospected. In this surveyed portion alone there remains enough nitrate to supply the world for an additional 100 years, measured at the present rate of production. These calculations have been made on an extremely conservative basis, and take no account whatever of known areas of low-grade material.

The industry is divided into two principal operations: (1) mining and transportation of the crude material and (2) production of nitrate. Methods employed in both branches leave room for improvement. Under present practice, considering average value of raw material, wages, etc., the cost of producing commercial nitrate is estimated at 50 cents United States currency per quintal (101.44 pounds).

Trade specifications require a content of nitrate of sodium equal to at least 95 per cent. This is used as a fertilizer. The refined product, with over 96 per cent nitrate of sodium, is applied to manufacturing uses, such as glass, explosives, fusing mixtures, nitric acid, etc.

There can be no competition between Chilean nitrate

and atmospheric nitrate under any conditions which may be foreseen at present. The deposits of the great Pampa Salitrera (nitrate plain) are too vast and the business of manufacturing and marketing the material is too well systematized, whereas atmospheric-nitrate manufacture exists under too many limitations.

A natural reduction in nitrate production has followed the outbreak of the European war, many of the important consuming markets having been cut off.

The author has appended detailed data regarding nitrate production, method of transacting nitrate sales, results of experiments showing the advantages of using nitrate of sodium as a fertilizer, with special reference to crops raised in the United States, and other items of value covering the entire field.

The Turpentine Industry in the Southern States*

BY CHARLES H. HERTY, PH.D.

A railway trip through the coastal plain of the South Atlantic and Gulf States, from North Carolina to Texas, shows on every side fallen and charred remnants of trees, stumps innumerable, and occasional huge piles of sawdust. It is a desolate scene in those sections where agriculture has not yet been developed. It represents the destructive path of the naval-stores industry, followed more or less closely by that of lumbering, through that rich, natural heritage of long-leaf pine forests which originally covered completely this entire portion of the country.

From these forests the world has received its chief supply of spirits of turpentine and rosin, averaging in value in recent years some \$40,000,000 or \$50,000,000 annually. Yet in the production of this great crop only a very few have received for their toil more than a bare livelihood. The great mass of the turpentine operators have toiled throughout the years in rugged earnestness, in robust health from the out-of-door life in the pine forests—but always on the outer edge of developing civilization, with few of the comforts and conveniences

of life, indifferent to the utter lack of efficient business methods in their operations, and strongly wedded to woods practices which have been handed down from generation to generation as they steadily moved from North Carolina toward Texas.

If the traveler, however, should leave the main lines of travel in Florida or the more westerly states, and by tram or team reach some of the more remote sections, he would find beautiful virgin forests of this same long-leaf pine, the rich brown trunks of the trees, free from low-lying limbs, bearing aloft rich crowns of green, and firmly rooted below in a soft carpet of the same hue, formed by the "wire grass" which abounds throughout this territory.

Will the operator, in the exploitation of these remaining forests, profit by the demonstrated inefficiency of past methods? Can he change his attitude of thought toward the living tree on which his operations are based? Is he willing to place himself in line with all other lines of modern industrial life, which have realized, or are beginning to realize, that true progress in any industry must be based, not upon individual opinion or hereditary teachings, but upon scientific research and constant striving for greater efficiency?

Upon the answer to these questions depends largely the future of the naval-stores industry. This is not a matter for indefinite proceeding along inefficient lines; the actual life of the industry is threatened, for the once-considered inexhaustible forests are rapidly disappearing. At the present rate of destruction the end can be fairly well forecasted, especially since no effort is being made toward reforestation.

It was natural that destructive methods should have characterized this industry, for the early settlers in eastern North Carolina found forests of long-leaf pine everywhere. Clearance was necessary for agriculture, crops had to be grown, lumber was needed for industry, homes had to be built, and so the work of destruction began.

It was immediately recognized that this tree, when wounded, is a prolific producer of an oleoresin, "crude turpentine." Furthermore, the rich resinous wood, when heated out of contact with air by piling in heaps and covering with earth, gave off a rich distillate of tar,



FIGS. 1 TO 3—BOX SYSTEM

FIG. 1—CUTTING THE BOX

FIG. 2—CORNERING THE BOX

FIG. 3—CHIPPING THE FIRST STREAK ABOVE THE VIRGIN BOX

*A paper presented at a joint meeting of the Franklin Institute and the Philadelphia Section of the American Chemical Society.

which could be boiled down to a pitch. These products, tar and pitch, were much needed for the wooden ships with their extensive rigging, at that time universally in use; and so along with agriculture, with its yearly crops, there developed the naval-stores industry with its constant output of immediately marketable products.

The method of conducting the industry called for no plant other than the forests, and so when the yield of the trees began to decrease after two years of operation, new tracts were opened, and the industry began its march southward, from North Carolina into South Carolina, thence into Georgia and Florida, and then rapidly expanding into the Gulf States, though on a smaller scale.

In the early days in North Carolina no effort was made to separate the crude turpentine by distillation into its constituents, spirits of turpentine and rosin, the gum being shipped to Northern cities or to England for such manufacture. In the early part of the past century, however, this manufacture was transferred to the woods, iron stills being at first employed, which later were replaced by the more efficient copper stills such as are used to-day for this purpose.

In the woods, however, there was no corresponding advance in methods of operation, with the exception of slight improvement in the tools employed. Thus for more than a hundred years the method of wounding the tree and collecting the gum remained the same throughout the turpentine belt.

The normal routine on all turpentine farms consisted of the following operations:

"Boxing."—In the winter negro laborers, under the direction of a white woodsman, cut "boxes." The box was an elliptical cavity cut in the base of the tree, usually just above the junction of a prominent root with the trunk of the tree. It served to collect the gum which flowed during the warmer months from the scarified surface above. The tool used in cutting this box was a very long, narrow axe, the negroes developing consummate skill in the use of this "box axe." The standard dimensions of the box were 14 in. width, 7 in. depth, and $3\frac{1}{2}$ in. from the outer wood toward the center of the tree. The number of boxes per tree was increased from one to four, and occasionally five, according to increasing diameter of the trees.

"Cornering."—Box cutting was followed by "cornering." This consisted of removing two triangular chips from immediately above the box by means of the usual wood-chopping axe. The function of cornering was to provide smooth surfaces to direct the flow of the gum into the box.

"Chipping."—As vegetation became active in early spring the work of scarification of the trunk of the tree began, and continued weekly for eight months. The repetition of this process was necessary, as the flow of gum, greatest during the first three days following the fresh chipping, practically ceased after one week. The tool employed in chipping, called a "hack," was a stout U-shaped steel blade attached by a metal shank to one end of a round wooden handle. This handle carried on its other end a heavy iron weight which gave momentum to the free arm stroke used to draw the blade through the bark and outer sapwood. A slightly modified form of this tool, called the "puller," was mounted on a much larger handle, with no iron weight attached, and was used for the higher reaches of the third and fourth year of scarification.

"Dipping."—At periods of four to five weeks, when, in the judgment of the woodsman, the boxes showed an average filling, the gum was removed into buckets by a broad, flat, spear-shaped tool, called a "dip spoon." Bar-

rels placed at convenient distances in the woods received the gum from the buckets, and were then hauled to the "still" for distillation.

"Scraping."—As the chipping season progressed not all of the gum found its way to the box, for as crystallization of the gum began some of this mass remained sticking to the exposed surface of the tree. At the close of the chipping season this accumulated resinous mass was scraped from the trees, thus giving the name, "scrape," to the product. Its content of spirits of turpentine was much lower than that of the gum from the boxes.

"Raking."—With the completion of the scraping, the final operation was the protection of the trees from the ground fires which prevail throughout the turpentine belt in late winter when the dead wire grass is burned. Such protection, "raking," was effected by means of a common hoe, all combustible material, chips, pine needles, and dead grass, being removed to a distance of about 2 ft. from the base of the tree.

This completed the year's operations in the woods, and the cycle was then renewed from year to year.

The severe strictures on the wastefulness of the industry spoken by the German technologist, Otto N. Witt, led to the determination on the part of the writer to investigate whether or not this criticism was deserved. Correspondence with men familiar with the industry, and a brief visit to a turpentine farm in South Georgia, afforded ample proof that conditions were even worse than had been depicted.

With such waste prevalent, could not something be done to improve the situation? Here the methods of work learned through research in a chemical laboratory asserted themselves. A search of the literature was begun and made as comprehensive as possible. The results of this study and of observations in the woods made clear the fact that the great evil of this industry, that which more than all else was responsible for the waste and destruction, was the cutting of the "box" in the base of the tree. This deep cavity, located just where the strain was greatest, caused many of the trees to fall in even slight windstorms. It constituted a great source of danger during fires, especially after turpentine operation had ceased and the tree no longer was protected by the annual "raking." The decreased vitality of the tree, due to the severe wound, led in many cases to easy attack by injurious insects. Such evils were easily noticeable, but others, less readily seen, were found upon closer study. With a receptacle at a fixed point, while the distance between the receptacle and the freshly-chopped surface increased regularly from week to week, opportunity was thus afforded for increasing loss of the volatile oil by evaporation, for coloration of the rosin by absorption of oxygen from the air under the influence of sunlight, and for waste in dripping outside the box. It seemed reasonable, moreover, that this severe wound would so decrease the vitality of the tree as to cripple, at least to some extent, the power of the tree to produce crude turpentine. The "box," therefore, should be the primary point of attack in any effort to conserve these forests.

To overcome the evils of the "box," a substitute receptacle must be provided which should inflict but a slight wound in placement on the tree; should be capable of removal at convenient intervals to a point just below the chipping surface; should be extremely simple in its construction in view of the gummy character of the product it was to receive; easy of operation, because of the unskilled labor which would use it; and cheap, if hopes were to be entertained of its commercial introduction by those who are abundantly satisfied with existing methods and fully convinced that

no better could be found—an unfortunate state of mind, in these days of progress.

The literature of the French system of turpentineing was then studied, and the records of the Patent Office were thoroughly searched. Nothing, however, was found quite free from objections to its ability to meet the above requirements, especially as applied to the system of chipping as practised in the Southern States. In the light gained from this study, however, a substitute was devised, consisting of a simple cup suspended, through a hole near its rim, on a common nail. Into this cup the gum was to be directed by two shallow galvanized iron troughs or gutters, to be inserted about $\frac{1}{4}$ in. deep by one of their long edges in correspondingly shallow inclined cuts across the scarified surface of the tree.

With this apparatus provided, and again following the procedure of laboratory research, preliminary experiments were begun, during the summer vacation of 1901, in the forests of southwest Georgia, near the town of Statesboro, on timber provided, after much persuasion, by some of the leaders of the industry in Savannah, Ga., who viewed their concessions with an eye of infinite skepticism.

The results of these preliminary experiments were the thorough demonstrations of the efficiency of the apparatus, a deeper grasp of the problem to be solved, a genuine sympathetic interest with the personalities of many employed in the industry, and much knowledge of the habits of the pine. It was completely demonstrated that the dark color of rosin produced under the box system, after the first year of operation, was not at all due to physiological changes in the pine, but solely to the method of collecting the gum. Under this system opportunity was offered for increased oxidation and for absorption of the deeply-colored gum coating the exposed surface, formed by the shipping of previous years. This was important, as the commercial value of the rosin decreases as the depth of color increases.

The United States Bureau of Forestry, hearing of the proposed preliminary experiments, tendered the writer a collaboratorship in order to secure publication of the results. The experiments were so full of promise that it was agreed that the work should be promptly resumed at the opening of the next season, with field experiments on a commercial scale, under the auspices of the Bureau of Forestry. Accordingly, the experiments were begun in February, 1902, on the turpentine farm of Powell, Bullard & Company, a well-known firm operating in southeast Georgia, near the town of Ocilla. For these experiments the following policy was adopted at the outset:

1. The timber was to be provided by the firm, the cups and gutters and cost of installation by the bureau.
2. The labor was to be none other than such as was employed in the regular work of the farm.

3. The experiments were to be restricted solely to the "box" question and the practicability of the substitute cup and gutters. Therefore the work of chipping, dipping and scraping should be conducted in the normal way.

4. Four sets of comparative experiments were to be conducted simultaneously, one on virgin timber and three on boxed timber which had already been operated respectively one, two and three years. This would determine, so far as possible in one year, the influence of the box on the timber and on the income of the operator.

5. The results should be taken from the records of the company, whose statements would be readily accepted by all other operators.

So far so good. Then troubles began. The manufacturer, delayed in his work, did not deliver the equipment until the chipping season was nearly at hand. This led to a shortcoming, undreamed of at the time, and which in after years caused the loss of many thousands of dollars, but this will be discussed later.



FIG. 4—CUP SYSTEM; GUTTERS AND CUP IN POSITION



FIG. 5—CUP SYSTEM; UNBOXED TREE WITH CUP AND GUTTER IN POSITION AT END OF FIRST YEAR'S CHIPPING, SHOWING CORRECT POSITION



FIG. 6—CUP SYSTEM; "DIPPING" THE CUP

Next, labor troubles were unexpectedly encountered. The negro laborer proved even more conservative than the white operator and woodsman, and assumed the remarkable attitude that the "flower-pot" method of making turpentine was more properly the work of women and children, and not suited to the dignity of full-grown men. This may be difficult of belief, and it was strange in the light of later developments, but it proved a serious obstacle for some time. By dint of patience, tact, and kindly reasoning this trouble was at last overcome sufficiently to enable a beginning of work in the woods with three laborers, but up to the very moment of actual handling of the axe the chagrin and mortification of those three negroes, too inefficient for the regular box-cutting squad, were comical, though the situation had its serious side in that the whole question of the carrying out of the experiments was at stake in the successful solution of this labor difficulty.

It is sufficient here to state that in a short while the problem was completely solved, and as success in the experiments became more and more marked the comical picture then became the rather haughty air and proud demeanor of those who gleefully dubbed themselves "cup niggers"!

To return to the experiments: three crops were selected, consisting each of 10,000 boxes, the unit of operation. These three had already been under operation one, two and three years respectively. On one-half of each of these crops cups and gutters were installed near the point where the chipping would begin. On the other half the gum was collected in the normal way, in the box, at the base of the tree. These experiments would determine the practicability of the equipment at varying heights on the tree; the quality, as to color, of the rosin produced from gum collected under the two systems, and would give some information as to relative waste from evaporation, etc.

The main interest, however, centered in the experiment on virgin timber, where the two systems could be

put into operation under fully equal conditions. For this experiment a tract of timber of fair average quality was selected by the firm just outside of the town.

To insure accuracy of the experiment, this timber was carefully and repeatedly cruised by experienced woodsmen, and a division made as to location of cups and boxes respectively. In this division it was decided to alternate the "drifts" (subdivisions of a crop) of cups and of boxes. This also furnished more uniform weather conditions in working the two halves. The entire crop was to be chipped by one man, and the dipping was to proceed every three weeks, simultaneously in the cupped and boxed halves of the crop, the gum to be collected in different sets of barrels. The presence of varying trash and water would render inaccurate the results from measuring or weighing the gum. Therefore it was distilled and record kept of the number of gallons of spirits of turpentine obtained from each lot, and separate sales made of the rosin produced. No difference in quality of rosin was expected or found here. As the distance of flow of the gum was the same in each set, loss of spirits of turpentine by evaporation was equalized.

All precautions were taken so that whatever difference of results might be found in the yields from the two halves could be ascribed to no other factor than the influence of the severe wound caused by box cutting on the productive power of the trees. The advancement of the idea that it decreased productive capacity had met with hoots and jeers on all sides, and here in this crop, it was felt and stated without the least effort of repression, would be demonstrated the superiority of the judgment of the "practical" man over the theoretical college professor.

The work of installation began. Two flat faces meeting in a central line were cut with common axes to adapt the round tree to the straight-edged gutters, two laborers with broadaxes made across these plane surfaces the incisions for the gutters, which were promptly inserted by another group of laborers, the upper gutter reaching just to the center of the face emptying into the opposite gutter equally inclined, running about 1 in. lower and extending about 2 in. beyond the angular center of the face, to provide a suitable hanging of the cup into which all of the gum dripped. While awaiting the arrival of the cups and gutters, the box-cutting squad and the "cornerers" had been gleefully at work in the other half of the crop.

With the respective receptacles provided and installed the work of chipping began—and the race was on. The detailed results are given in Table 1.¹

¹The tables throughout this paper are from Bulletins 40 and 90 and Circular 34 of the U. S. Forest Service.

TABLE I—FIRST-YEAR CROP—DIPPINGS

Number of Dipping	Date of Dipping	Number of Chip-pings	BARRELS OF DIP OBTAINED		SPIRITS OF TURPENTINE ON DISTILLATION (GALLONS)		EXCESS SPIRITS OF TURPENTINE (GALLONS)	
			Boxes	Cups	Boxes	Cups	Boxes	Cups
1	April 14	3	91	117	101.6	84.3	17.3	
2	May 5	3	91	101	111.0	130.5		19.5
3	May 26	3	12	14	136.8	178.3		41.5
4	June 16	3	123	171	143.3	191.2		47.9
5	July 7	3	123	145	142.4	175.2		32.8
6	July 28	3	103	123	115.2	141.7		26.5
7	Aug. 18	3	10	11	106.6	126.6		30.0
8	Sept. 8	3	8	102	86.1	105.9		19.8
9	Sept. 29	3	73	91	80.0	100.0		20.0
10	Nov. 4	3	110	122	110.9	145.6		34.7
Total		32	1011	1211	1,134.7	1,385.3	17.3	267.9

¹Including rosin from box cutting and coroeoring.

²Including rosin from placing cups on trees.

³Boxes dipped after trees have been scraped.

The unexpected shortage from the cups on the first dipping led to great rejoicing among the box supporters, and to undoubted apprehension on the part of the solitary backer of the cups. The second dipping, however, altered the situation, and by the last of June the victory for the cups was so complete that all were converted. The beginning of the end of the box system had been reached. From this point on all went well. Labor was anxious to enlist, enthusiasm had supplanted scoffing, and now the chief effort of the original cup backer was to guard against possible inflated results, due to some over-zealous convert, which results might not be justified by the facts in the case, for in spite of convictions formed in advance of experiment it was, as in all research, the truth which was sought.

Several years passed, much thought was expended, and many experiments were made before the true interpretation of that shortage on the first dipping was obtained and its remedy provided. This will be discussed later.

Meanwhile the distillation of the gum from the second, third and fourth year crops showed uniformly high-grade rosin from the cups, as contrasted with the low-grade rosin from the corresponding boxes, and the equipment proved itself readily adaptable to the increasing heights of chipping.

The results of net rosin sales from all four crops are given in Table II.

TABLE II—SEASON'S RECORD OF NET ROSIN SALES

Half Crop	From Dip	From Scrape	Total	Excess Net Sales	Per Cent Excess Net Sales, Cupped Trees
First year:					
Cups	\$401 72	\$47 72	\$449 44	\$45 51	23.50
Boxes	328 40	35 53	363 93		
Second year:					
Cups	266 34	49 25	315 59	144 13	84 64
Boxes	104 51	66 95	171 46		
Third year:					
Cups	171 27	37 44	198 71	132 65	200 80
Boxes	39 49	26 57	66 06		
Fourth year:					
Cups	167 33	29 23	196 56	132 56	207 13
Boxes	36 09	27 91	64 00		

The experiments with the second, third and fourth-year crops were discontinued at the end of the year, having served their purpose. The working of the virgin crop, however, was continued two years longer. The complete results for the three years' operation of this crop are given in Tables III, IV, and V.

That the distribution of the timber in this virgin crop had been well equalized was shown by measurements of diameters of all trees in the crop and by a determination of the average number of cups or boxes per tree throughout the crop.

As the work progressed, careful record of the dead and down trees were made in each half. The count at the end of the three-year period is shown in Table VI.

During the chipping season portions of some of the chipped surfaces became unproductive, locally termed "dry face." The results of the measurement of the extent of "dry face" in the two halves of the crop showed an excessive amount in the boxed half at the end of the first year. From that time on the amounts, while increasing in each, showed less striking difference. Evidently the cause of increased "dry face" in the last two years lay more and more in the chipping, and this observation led to later valuable experiments on comparative yields from lighter chipping.

The results of the first year's experiments were communicated to the turpentine operators at their annual convention. Much interest was aroused and some enthusiasm. The next few months, however, proved an

TABLE III—SPIRITS OF TURPENTINE FROM HALF CROPS

Year	CUPS			BOXES			Excess from Cupped Half Crop, Gallons	Net Price per Gallon at Time of Operation Cents	Value of Cup Excess
	From Dip, Gallons	From Scrape, Gallons	Total, Gallons	From Dip, Gallons	From Scrape, Gallons	Total, Gallons			
First.....	1,385.3	205 0	1,590.3	1,134 7	153 7	1,288 4	301.9	40	\$120.76
Second.....	1,103.5	165 0	1,268.5	705.2	226 6	931.3	336.7	45	151.52
Third.....	781.3	136 0	917.3	536 1	190 5	726 6	190.7	45	85.82
Total.....	3,270.1	506 0	3,776 1	2,376 0	570 8	2,946 8	829 3		\$358.10

TABLE IV—NET SALES OF ROSIN FROM HALF CROPS

Year	CUPS			BOXES			Excess from Cupped Half Crop
	From Dip	From Scrape	Total	From Dip	From Scrape	Total	
First.....	\$401 72	\$47 72	\$449 44	\$328 40	\$35 53	\$363 93	\$85 51
Second.....	286 88	58 24	345 12	132 42	84 08	216 50	128 62
Third.....	212 60	61 65	274 25	124 76	79 70	204 46	69 79
Total.....	\$901 20	\$167 61	\$1,068 81	\$585 58	\$199 31	\$784 89	\$283 92

TABLE V—SUMMARY OF GAIN FROM CUPPED HALF CROPS

Years	Spirits of Turpentine	Rosin	Total
First.....	\$120 76	\$85 51	\$206 27
Second.....	151 52	128 62	280 14
Third.....	85 82	69 79	155 61
Total.....	\$358 10	\$283 92	\$642 02

TOTAL VALUE OF PRODUCTS FROM THREE YEARS OF OPERATION

Cupped half crop	\$2,688.55
Boxed half crop	2,046.53
Gain from cupped half crop	\$642.02 = \$1,284.04 per crop

TABLE VI—RECORD OF DOWN AND DEAD TREES

	NUMBER OF TREES BLOWN DOWN		NUMBER OF TREES DEAD	
	Boxed	Cupped	Box	Cupped
In 1 year.....	8	3	35	16
In 2 years.....	60	34	139	93
In 3 years.....	78	44	217	150

interesting testimonial to the "follow-up" policy of the wise advertiser, for, in the three-month period spent in arranging for the manufacture of the equipment at a reasonable cost and in the preparation of an account of the experiments for publication as a government bulletin, interest in the matter completely disappeared. It was only through the most persistent efforts that interest was sufficiently re-aroused, in those at one time enthusiastic, to assure the commercial utilization of the rather limited output of the cup factory.

The first season's use of cups by the operators assured the future, the results obtained more than confirming the experimental results of the previous year. Instantly the demand increased; prejudice slowly gave way; the quality of the cups was improved with increasing experience at the factory; timber owners made concessions in price of leases, provided cups instead of boxes, eventually stipulating that timber could not be worked if box cutting was the intention, and labor throughout the territory became familiar with and enthusiastic about the new method. Thus was the box system, with its attendant losses, replaced by the more efficient cup system. To-day box cutting is practically a thing of the past, while many forms of cups, to suit

individual requirements, have become every-day articles of commerce.

From the outset, railway officials of the Southern States, keenly alive to the welfare of the territory tributary to their lines, were strongly sympathetic with this movement, and by their prompt and intelligent handling of the question of freight rates on the equipment, facilitated greatly the universal introduction of the new method.

To encourage the adoption of the new system, the Forest Service adopted the wise policy of offering, free of cost to the operators, the services of the writer in inaugurating the work on a turpentine farm. Never to be forgotten was the first experience in this work of instruction, when, on a cold, drizzly February day, at a south Georgia sawmill, there was handed over for instruction a group of sixteen young negro convicts, in characteristic garb and utterly devoid of any knowledge of turpentine operations. The situation seemed impossible and hopeless, but the future of the work was at stake. Fortunately, experience gained in years of teaching in the classroom came to aid. The setting was entirely changed, but the methods of pedagogy were applicable and necessary. The effort succeeded. After such an experience all others were easy.

The "practical man," however, had his inning, for a little later, working in timber near the Gulf Coast of Florida, it was found that such timber was so tough that it was impossible to make smooth, flat faces on the tree for the gutters with the ordinary axe employed. After a long day of struggle, with defeat clearly ahead, the turpentine operator suggested the use of the broad-axe for this purpose. The experiment was tried and immediately succeeded. Later another step forward was taken by the suggestion of another operator that in hewing with the broadaxe the bevelled side of the edge be placed next to the tree. This was revolutionary from an axeman's point of view, but it was tried and its advantages were immediately noted, for there was no difficulty in forcing the axe to the surface at the base of the cut, thus saving the tree useless wounding and so increasing the speed of operations that in a little while it was possible, with an equal force of laborers, to install three crops of cups while one crop of boxes was being cut. Such details may appear trivial, yet each had its influence on the rapid introduction of the system.

As reports began to arrive concerning commercial experiences with the system all agreed on increased yield, but all agreed likewise on the unusually large number of chippings required to fill the cups with gum at the beginning of the season, especially when compared with boxes on similar timber near the cupped tree, the capacity of cup and box being the same. After this first dipping the superiority of the cup system readily showed itself in largely-increased yields. Here was a recurrence of the mortifying experience with the first dipping of the virgin crop in the experiment at Ocilla. What could be its explanation? How could the trouble be overcome? Various suggestions were made and numerous experiments tried by men of all types in all sections, but without success in overcoming this chief defect in the system.

A few years later the writer had opportunity to visit Prof. A. Tschirch in his laboratory at Berne, Switzerland, and there learned his views concerning resin flow, views based on the results of experiments on many pines in the neighborhood. According to Tschirch the resin ducts, found scattered throughout the wood of a normal pine, contain a resin which is formed as a result of natural life processes in the living tree. Such a product is, therefore, a purely physiological product, and

such ducts he designated "primary resin ducts." These yield only a small quantity of crude turpentine when the tree is wounded. Immediately after the wounding, however, there begins in the outer fresh wood the formation of a very large number of resin ducts, both above and below the wound, forming an anastomotic system, which pour out crude turpentine in great quantity as a healing balsam over the wound. Such an exudate is a pathological product, and the ducts producing it he termed "secondary resin ducts." These extend 4 to 5 in. above the wound, requiring four to five weeks for their full development.

In the light of this knowledge the explanation of the excess yield of the boxes over the cups on the first dipping was simple. When the boxes were cornered a full-width, V-shaped surface was formed above which the secondary resin ducts formed in abundance during the several weeks which elapsed before the chipping season began. Then when the first chipping was made the cut traversed secondary resin ducts along its full length and a maximum yield was obtained.

On the other hand, the late arrival of the cups for the experimental work made it necessary to begin chipping immediately afterward. The secondary resin ducts had not fully formed during this brief interval, and there was a correspondingly low yield of crude turpentine, which, however, rapidly increased later as the ducts increased.

Again, in explanation of the same difficulty experienced by operators who placed their cups on the trees many weeks in advance of the chipping season, it must be remembered that the flat faces for the gutters were then being made on the tree by the broadaxe. The cutting of a straight-edged tool into a round tree exposed the fresh wood above in the form of two curved lines, meeting at the center of the cut surface. Again, the secondary resin ducts formed, but following the outline of the cut. When, therefore, these trees were chipped, only about half of these ducts, those near the center, were traversed by the downwardly-inclined stroke of the back. Hence a flow of gum far below that in the box system, but again rapidly increasing after the first full-width cut formed by the first chipping.

This suggested a simple method for overcoming the losses encountered during the first six or eight weeks of operating under the cup system, namely, the placing of the gutters on the trees in winter should be followed immediately by one full-width chipping and the trees allowed to stand, without further chipping, four or five weeks. Opportunity would thus be given for full formation of the secondary resin ducts along the full width of the chipping surface, as in the box system.

These views were laid before a number of operators using the cup system, and they were requested to try the modified method on some of their timber during the next winter. They agreed; the experiments were carried out, and in every case the cure for the evil was found to be complete, cups so placed yielding a greater amount on the first dipping than boxes, or than cups placed without the one winter chipping. Conservative estimates made by experienced operators place the total annual gain from this slight modification of woods practice at not less than \$500,000. Could there be asked a better illustration of the value of pure university research, as was that of Tschirch, for efficient industrial operation?

With the future of the cup system assured, attention was next turned to the relative yield of crude turpentine with reduced wounding of the tree in chipping. These experiments were conducted near Green Cove Springs, Fla.

In order to interpret the results clearly, all trees were

cupped, and one of the crops chipped to normal depth, 7/10 in. into the new wood, the thickness of the chip being such as to carry for chipping up the trunk at the normal rate. This crop was designated A.

In another crop, designated B, the depth of the chipping was reduced from 7/10 in. to 4/10 in., all other conditions being identical with the standard crop A.

In a third crop, designated C, the thickness of the chip was so reduced that the same elevation on the trunk would be reached in four years as was reached in three years in crop A, all other conditions being alike in the two crops.

Finally, in a fourth crop, designated D, no tree under 10 in. was worked; the minimum diameter for trees bearing two cups was raised from 12 in., as in crop A, to 16 in., and, finally, no tree bore more than two cups, regardless of its larger diameter. In this crop the chipping was the same as in the standard crop A.

The results of the four years of work on these crops are given in Table VII.

TABLE VII

Crop	DIP		SCRAPE		
	Yield Pounds	Increase Per Cent	Yield Pounds	Increase Per Cent	Decrease Per Cent
A	206,235		47,742		
B	211,941	2 73	44,838		6 08
C	214,503	4 91	39,773		16 69
D	279,290	35 41	53,915	12 93	

The marked success of these experiments led to a further experiment for one year, in which was compared with a standard crop, such as A above, the yield from two crops, designated G and H, in which both modifications of chipping, shallow and thinner cuts, as in B and C above, were combined. The results are given in Table VIII.

TABLE VIII

Crop	Number of Cups	Number of Chippings	Yield of Dip, Pounds	Increase, per Cent
Wallkill Turpentine Company	9,880	35	90,094	
G	9,880	35	124,292	38
H	9,880	35	121,474	35

This was the way clearly pointed out for more conservative treatment of the trees, the result being largely increased yields.

Are further experiments on the reduction of the wound in chipping justified? This is a difficult question to attempt to answer. Certainly there is a limit to which such reductions can be carried, beyond which financial loss will result, under existing conditions of cost of stumpage and wages of labor. If the tree is not wounded, crude turpentine is not produced; if it is girdled, the tree dies. Somewhere between these extremes lies the most efficient operation. From the results already mentioned it is evident that past practice in chipping has been on the side of too excessive wounding. Whether or no the limit should be further reduced can be determined only by experiment.

One abuse, however, has arisen in connection with the spread of the cup system, namely, the general practice of cupping very small trees. Such trees were not brought into operation under the box system, as they were too small to receive a box, but they could be cupped with ease. Two strong objections hold against this practice: First, the trees of the future naval-stores industry are being destroyed, a well-marked case of child-labor abuse for which there is no legislative cor-

rection. Second, the judgments of the leaders of the industry agree that the operation of such small trees is unremunerative in itself, yet often producing sufficient crude turpentine to seriously depreciate the market value of that produced from the larger trees.

Much has been spoken and written by these leaders against the practice, but still it continues. Is not experiment advisable here? The following is suggested, and it is hoped that the suggestion will receive the consideration of the United States Forest Service. An investigation is needed of what is the actual yield from a crop of 10,000 of these very small trees during a period of three or, better, four years of operation. Such an investigation would give facts where now mere opinion prevails. The experiment would not be costly, because it could be carried out in connection with the regular operations of a turpentine farm. It would require only efficient supervision; the dipping from the small trees to be kept separate from those of unquestioned size, say 10 in. and over, in diameter; the yields from the two lots compared, and the results published for the benefit of all. Such a publication would constitute a valuable contribution to the literature of this subject, and such facts would carry far more weight than any amount of spoken or published criticism.

Leaving now questions connected with woods practice, let us follow the barrels of gum to the distillery, or "still," as it is uniformly called. This manufacturing plant is exceedingly simple, and, as a rule, roughly built, the rapidly-shifting character of the industry not justifying more pretentious housing. A large copper kettle, the "still" proper, is set in brick masonry above a firebox in which pine wood is burned. Eight to ten barrels of the gum, mixed with chips, dirt, and some water, constitute a charge, the distillation of which requires from three to four hours.

The kettle is connected by a removable "still head" to a coiled copper worm, set within a large wooden tank, the condenser, into which cold water flows or is pumped at the bottom, cooling thus the hot mixed vapors of steam and spirits of turpentine in the condenser coil. The heated water is led off by an overflow or is partly used by running along a narrow trough leading from the top of the condenser to a small, funnel-shaped opening in the lower part of the still head, and emptying into the still and on to the boiling gum below, the steam thus generated aiding materially the separation of the volatile spirits of turpentine from the non-volatile resin.

The proper regulation of this flow of water has been generally determined by the sound produced by the boiling mass heard at the mouth of the condenser. Recently the use of inset thermometers for the purpose of controlling the distillation has largely increased.

The condensed liquids, flowing from the mouth of the worm, separate at once in the receiving vessel into two layers. The lighter spirits of turpentine is pumped into large storage tanks or is dipped into oak barrels, which have been thoroughly coated inside with glue. It is now ready for marketing. When the volatile oil is practically all removed, the still head is taken off, and the chips are skimmed. In the case of virgin dip this skimming is done as soon as the gum melts and before distillation begins.

Finally, when all water has boiled off, a necessary precaution to prevent the rosin being opaque, the molten rosin is allowed to flow from the still through a tail pipe, leading from the bottom of the still, to two strainers placed the one above the other. The upper strainer consists of coarse wire gauze, and retains unskimmed chips. The lower strainer, of fine brass gauze over which are placed layers of cotton batting, retains

the dirt and smaller portions of trash. From these strainers the rosin flows into a long wooden vat, from which it is promptly dipped into barrels, where, upon cooling, it solidifies and is then ready for shipment.

Crude as the method appears to the casual observer, nevertheless careful study of this system as compared with the much more expensive systems in France has convinced the writer that, given a good stiller, equally good results are obtained by this very inexpensive outfit. Of course, the presence of the personal element, as represented by the stiller, is always a risk in manufacturing operations, and it would seem to be a needless risk in the light of its complete elimination in the French system of "mixed injection," where heating is effected partly by free flame and partly by steam; where water vapor is furnished both by inflowing hot water and by direct injection of steam, and where operations are controlled entirely by the thermometer. Such plants are not expensive and are very simple in operation.

The suggestion has recently been made that this industry would be placed on a much more efficient basis if the smaller stills in the woods were done away with, the gum hauled in tank cars direct to a central distillery, advantageously located, and there distilled. This suggestion contains many thoughts which justify the belief that here lies the way to the next decided step forward in the evolution of this industry, if questions connected with transportation can be properly worked out.

Undoubtedly there is much waste at the present small distilleries. Important matters concerning utilization of by-products cannot be properly handled under the present system. Much demoralization of labor arises from the still being near the turpentine camp.

On the other hand, the handling of crude turpentine in sufficient quantities at a central distillery would justify the presence of the most efficient forms of stills and of labor-saving devices common to all handling of material in large quantities.

Of possibly still greater importance is the fact that operations on such a scale would justify the employment of competent chemists, who, in addition to the careful control of the operation of the distillery, could supervise the manufacture of rosin oil directly from the molten rosin, of the various commercial articles into which such products enter, and who could by systematic research find new uses for and new transformations of the various products, thus guiding the industry to wider fields of application, and enabling it to more fully keep abreast of that progress characteristic of all industries which wisely make use of the services of well-trained chemists.

University of North Carolina,
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Course in Gas Manufacture and By-Product Recovery at Johns Hopkins University

The Department of Engineering of the Johns Hopkins University has organized and is now giving a course in gas manufacture and by-product recovery for such students of engineering or chemistry as desire to prepare themselves for entering this important field of industry. The work may be elected during the fourth year of the courses in mechanical, electrical or civil engineering, and may be pursued as graduate study. The course is also open to graduate students in either chemistry or engineering, and may be elected by such fourth-year undergraduates in chemistry as are able to qualify for the work. It is highly desirable that those taking this work should have completed three years of undergraduate work in one of the branches of engineering.

This course involves essentially the study of the dis-

tillation of carbon and the utilization of all the products of the process. It deals with the principles underlying the gas industry and the production of most of the chemicals used in the industries of the world. The work is taken up in both lecture room and laboratory, for which special equipment is being provided.

The following broad outline indicates the scope of the lecture and laboratory courses:

(a) The physical and chemical properties of gases, including fundamental laws of gases, kinetic theory, liquefaction, dissociation, viscosity and flow of gases; nature and velocity of chemical reactions; chemical equilibrium; influence of moisture, surface and pressure in gas reactions; occlusion of gases, principles of thermochemistry.

The mechanism of combustion; ignition points; flames and explosions; combustion of carbon; carbon monoxide; carbon dioxide; cyanogen, hydrogen, and all hydrocarbons; thermal decomposition of hydrocarbons; action of steam on incandescent carbon.

(b) The technology of fuel, including the mechanical theory of heat; specific and latent heats; heat of combustion of solid and liquid fuels; calorimetry; principles of gas analysis and manipulation; preparation of pure gases; fractionation of gas mixtures; collection and storage of gas samples; solubility of gases in liquids.

Discussion of solid, gaseous and liquid fuels—coal, coke, lignite—natural gas, producer gas, coal gas, water gas, petroleum and other oil fuels.

(c) By-product coking processes. Description and theory of the various chambers and retorts used in the carbonization of coal.

(d) Details of manufacture and purification; methods of distributing, storing and measuring gas; high and low pressure distribution.

(e) Economics of gas manufacture and distribution, financing, cost, accounting, rate making.

It has been found by the Johns Hopkins University that it is decidedly advantageous for engineering students to delay specialization until the fourth year of the undergraduate course, and the engineering work is arranged accordingly. Opportunity is thus afforded for a thorough grounding in mathematics, physics and chemistry, and for a study along various broadening lines before the student begins to devote his time to any one special field. In the third undergraduate year each student takes courses in the elements of heat-power engineering, electrical engineering, and in the mechanics of structures.

The new course in gas manufacture and by-products is elected in the fourth year by those who desire to pursue that subject. Seventeen seniors and graduates are taking the work this year, the lectures being delivered by Capt. F. H. WAGNER, chief engineer of the Bartlett Hayward Company. Mr. Wagner is devoting the necessary time to this work because of his interest in seeing adequate facilities afforded at Johns Hopkins for instruction and research in this subject. It is hoped to erect a small coal-gas plant of one retort capacity, specially adapted for research work, in the laboratories.

It is the intention of the department of engineering to publish monographs covering the work done, copies to be distributed to those interested as soon as issued; besides this, the facilities of the laboratory will be available so far as possible for such special research work as may be of interest to the gas industry, full reports of results secured being published as soon as complete.

Unusual facilities are available in Baltimore and vicinity for studying the practical operation of by-product plants, as well as gas manufacturing plants, and the location is especially favorable for the experimental coal gas plant at Johns Hopkins University.

Cyaniding by Continuous Decantation at Two Nevada Silver Mills

(Editorial Correspondence)

Pittsburgh-Dolores Mill

In METALLURGICAL & CHEMICAL ENGINEERING for January, 1915, there appeared a brief outline of the proposed equipment and process to be used at the mill of the Pittsburgh-Dolores Mining Co., at Rockland, about twenty-eight miles south of Yerington, Nevada. This mill has now been in operation since June, 1915, and, by reason of the complete records kept, affords some interesting data on cyaniding by continuous counter-current decantation. It also provides an instance of the adaptation of an old plant to modern methods, for the original mill was designed for leaching only and has been converted to the use of an all-sliming process. The average tonnage treated based on actual operating time has been better than fifty tons per day.

The original roll-crushing equipment has been retained, although its deficiencies are recognized, the machines being of much lighter construction than is considered necessary in modern design. For fine grinding, a tube-mill has been added which runs in closed circuit with a Dorr classifier. The old leaching vats, 30 ft. by 5 ft., have been converted into Dorr thickeners, and three Dorr agitators, 22 ft. by 19 ft., have been added.

Crushing and Grinding

An average assay of the ore treated will show about 0.44 oz. gold and 3.4 oz. silver per ton. Moisture content will run from 4 to 5 per cent. The gangue is quartz and granodiorite, and parts of it are exceedingly hard. Coarse crushing is done in a Blake, 8 in. by 12 in., delivering a 1 to 1½ in. product to a wet trommel covered with ½-in. mesh wire screen. Cyanide solution is added at this point. The trommel products are further reduced by coarse and fine rolls, all being finally delivered to a second trommel covered with No. 13 ton-cap screen. Formerly a Bunker Hill screen was used for the final sizing, but the discharge for oversize was too small to handle a considerable quantity of talc which passed the crushers and it was displaced by the trommel. The oversize of the second trommel is returned to fine rolls and the undersize flows to the tubemill-classifier circuit. The elevator used in the crushing department has 8 in. by 14 in. buckets on a 16-in. belt and has a speed of 289 ft. per minute.

The tube-mill is 5 ft. by 18 ft. in size and is driven by a variable-speed motor which transmits power through gears and silent chain. Silex was originally used for lining and the mill was started with a load of 6 tons of Danish pebbles. Owing to the expense for pebbles and the high cost of transportation, hard mine rock was then substituted as a grinding medium, but this caused unusually rapid wear of the lining and after sixty days running time it was worn out and had to be replaced. The Belmont ribbed hard-iron liner was then installed, and the use of mine rock continued for grinding.

Cost of Tube-Mill Liners

Owing to the situation of the mill in the mountains at a distance of thirty miles from the nearest railroad point, hauling costs \$12 per ton, which will explain the high cost of delivering material at the mill site. The silex lining cost, delivered, \$450, and the labor cost of installing was \$75, making a total of \$525 for a lining that lasted sixty days. The Belmont liner, from

which a life of from fifteen to eighteen months is expected, based on other experience, cost \$1,230 delivered. Of this amount the railroad freight was \$257 and the wagon haul \$135. The cost of placing the lining was unusually high as the shell had to be drilled, this operation alone costing \$45. In the future the labor cost of relining should be about \$35, and this would give a total cost for the Belmont lining of \$1,265, or about two and one-half times the cost of silex. If, however, the Belmont gives from seven to nine times the life of silex, the former will be much cheaper in the end.

The hard ore used for grinding is sorted at the crusher, and about 3000 lb. is charged daily. The tube-mill is shut down temporarily, the man-hole cover removed and the ore run in through a chute from a storage bin.

The moisture content of tube-mill pulp is between 38 per cent and 40 per cent. The pulp flowing from the classifier will average about 75 per cent minus 200-mesh. Screen analyses are made dry, using Tyler standard screens, and each operation is continued until the oversize product has a constant weight. A few screen analyses are given herewith.

SCREEN ANALYSES, CLASSIFIER OVERFLOW

Mesh	Percentage			
	0.00	0.00	0.00	0.00
+ 35	0.00	0.18	0.25	0.30
+ 65	0.00	0.18	0.25	0.30
+ 100	0.00	0.40	2.45	2.40
+ 150	10.48	13.55	13.40	11.15
+ 200	9.20	13.30	10.30	12.08
-200	79.30	70.25	73.80	75.30

Equipment for Decantation

The old leaching vats converted into thickeners are rather shallow, but as the area is large and the ore settles readily no difficulty is experienced in discharging a thick slime. The vats were originally set on the same level, making it impossible to get gravity flow of solution through the decantation system. In order, therefore, to secure thorough mixing of the thickened slime and decanted solution passing to the various thickeners, mixing cones were first installed into which pulp and solution flowed and from which the mixture was elevated slightly to thickeners by air-lifts. Floats in the cones rigidly connected to the air line maintained a constant level of pulp. The scheme was tried for a time but finally the cones were discarded. At present the pulp is lifted by diaphragm pumps and the solution by air-lifts, and mixing takes place in the launders into which the two materials are discharged. The air-lifts for solution each consume from 3 to 5 cu. ft. of air per minute. The air consumption for each Dorr agitator is 9 cu. ft. per minute.

The decantation flow-sheets have been tried since operations commenced. The original scheme, shown in Fig. 2, placed all agitators in series between the



FIG. 1—PITTSBURGH DOLORES MILL

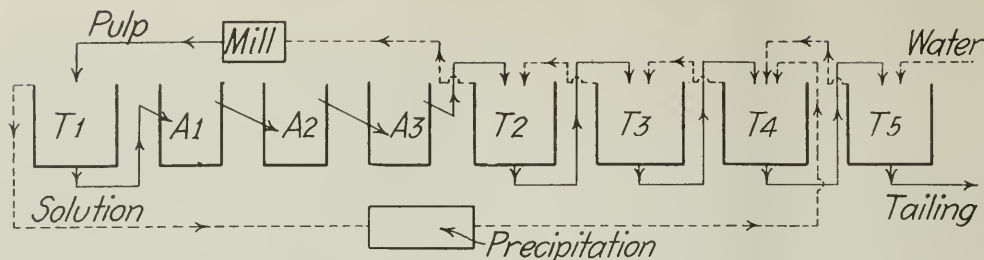


FIG. 2—ORIGINAL SCHEME OF DECONTATION—PITTSBURGH DOLORES MILL

first and second thickeners. This system was continued for about sixty days and complete data obtained on its operation. The scheme was then modified as shown in Fig. 3, introducing a decantation between the second and third agitators and thus giving the pulp a change of solution before final agitation. The effect was an increase in extraction of both gold and silver as shown by the reduction of undissolved loss from \$0.81 per ton in the first scheme to \$0.45 per ton in the second. The latter plan is now in operation.

Dissolved loss also was somewhat reduced, from 12.8 cents to 10.6 cents per ton, due probably to the fact that general operation was improved and further that the dissolution which probably occurred throughout the line of thickeners in the first instance was obviated by the change. Nevertheless reduction in dissolved loss probably was not as great as it would have been if an additional thickener had been added so that the customary four would follow agitation. The principle of changing solution between agitators has been quite well established in recent practice; but where this is done it is customary to add another thickener unless the ore is quite low grade. Otherwise three thickeners may not give sufficient opportunity for recovery of solution, and the dissolved loss will be unduly high. At the Rochester mill the extra thickener is in use, as shown in Fig. 5, and dissolved loss is lower than in the present instance. The use of four thickeners following agitation reduces solution values throughout that part of the system and consequently lowers dissolved loss by more than the 50 per cent which would be anticipated by the extra dilution. Thus in the present instance the dissolved loss of 10 cents per ton might be reduced to 4 or 3 cents by an additional thickener.

The essential data on the decantation process are given in Table I, where a comparison can be made between the results obtained by both methods.

The loss of dissolved metal per ton of dry slime is estimated by taking the average percentage moisture in the underflow of No. 5 thickener, multiplying by

the value of the solution contained and dividing by the per cent of solids. In this case the thickener underflow will average 50 per cent moisture, so that

TABLE I

Average results of continuous decantation by different flow-sheets, Figs. 2 and 3. Values figured at \$20 per oz. for gold and \$0.50 for silver; 24-hr. samples except as noted; pulp samples unashed (filtered and drained) except as indicated. Figures arranged according to sequence of machines in flow-sheet, Fig. 3. Abbreviations: F. S. = flow-sheet; T. = thickener; Agt. = agitator; U. F. = underflow; O. F. = overflow.

No. of Machine and Source of Sample	PER CENT SOLIDS		INDICATED EXTRACTION AT DIFFERENT STAGES		ASSAY VALUES, PULPS OR SOLUTIONS	
	F. S. Fig. 2	F. S. Fig. 3	F. S. Fig. 2	F. S. Fig. 3	F. S. Fig. 2 \$10 65	F. S. Fig. 3 \$9 12
Mill head						
PULPS—						
1 Tk feed	15 2	17 4	49 0	59 8	5 43	3 65
1 Tk U. F.	49 2	51 1	51 2	64 6	5 20	3 23
1 Agt.	30 4	36 1	72 5	73 2	2 93	2 44
2 Agt.	30 1	36 8	76 8	77 5	2 47	2 05
2 Tk U. F.	50 8	50 1	83 1	83 2	1 80	1 53
3 Agt.	29 4	32 3	78 2	87 4	2 32	1 15
3 Tk U. F.	49 7	49 4	87 5	89 9	1 33	0 92
4 Tk U. F.	53 0	49 3	89 8	92 0	1 09	0 73
5 Tk U. F., shift 1					0 88	0 51
5 Tk U. F., shift 2	52 2	50 4	91 6	94 2	0 94	0 53
5 Tk U. F., shift 3					0 87	0 53
5 Tk U. F., washed, 24-hr.			92 4	95 0	0 81	0 45
SOLUTIONS—						
1 Tk feed					2 25	2 21
1 Tk O. F.					2 14	2 04
1 Tk U. F.					3 01	3 03
1 Agt.					2 41	2 47
2 Agt.					2 48	2 56
2 Tk feed	17 0	15 7			1 40	1 02
2 Tk O. F.					1 28	1 03
2 Tk U. F.					1 29	1 13
3 Agt.					2 63	0 71
3 Tk feed	19 2	16 9				0 36
3 Tk O. F.					0 42	0 35
3 Tk U. F.					0 40	0 40
4 Tk feed	20 2	17 0				
4 Tk O. F.					0 14	0 14
4 Tk U. F.					0 24	0 18
5 Tk feed	35 4	32 7			0 19	0 10
5 Tk O. F.					0 13	0 09
5 Tk U. F., shift 1					0 17	0 10
5 Tk U. F., shift 2					0 13	0 10
5 Tk U. F., shift 3					0 14	0 10
5 Tk U. F., 24-hr.					0 14	0 10
Return solution					1 41	1 27
Zinc-box head					2 19	2 10
Zinc-box tailing					0 015	0 012
Dissolved loss per ton ore milled					0 128	0 106
Dissolved and undissolved loss per ton ore milled			91 2	93 8	0 938	0 561

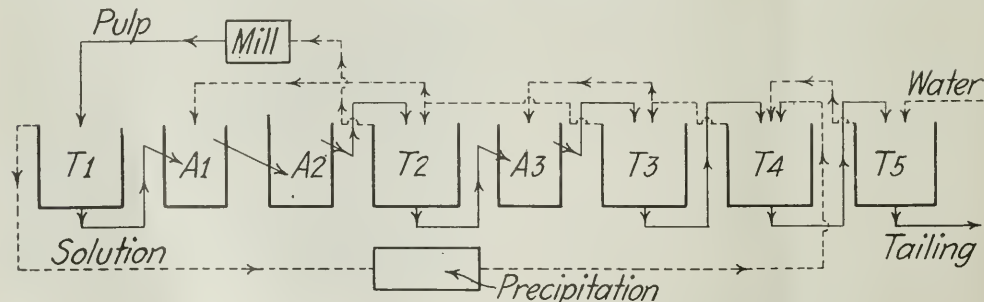


FIG. 3—MODIFIED SCHEME OF DECONTATION—PITTSBURGH DOLORES MILL



FIG. 4—ROCHESTER MILL

the value of the solution contained will be the dissolved loss per ton of dry slime.

A spring balance with a dial, such as is used in weighing parcel-post matter, is adapted to determining specific gravity of pulps. An arbitrary scale is prepared for the dial, indicating per cent solids, ratio of solution to solids, and specific gravity, so that these data can be read directly when a small bucket of slime is placed on the scale pan. If the bail of the bucket is made large enough to encircle the balance, the load can be suspended by looping the bail over the scale and its support, and thereby avoid spilling slime over the balance.

Pulp and solution samples from agitators and thickeners are taken hourly. The classifier overflow is sampled every half hour. The value of mill feed is determined by scoop sample of the dry crushed ore taken half-hourly at a plunger feeder.

Chemical Data

Aside from a high consumption of lime there is no unusual feature in the chemistry of the process. Some litharge is introduced at the tube-mill. Lime is added at the crusher and cyanide at No. 1 agitator. The strength of solution is 1.8 lb. KCN per ton, with 0.8 lb. CaO protective alkalinity. Consumption of chemicals is tabulated below in pounds per ton.

KCN (mechanical).....	0.5
KCN (chemical).....	0.1
CaO.....	14.0
Zn.....	0.8
PbO.....	0.4

The value of zinc-box head and tailing solutions is given in Table I. Under the scheme outlined in Fig. 2 about two tons of solution was precipitated per ton of ore; under the later scheme the ratio is about 3:1. Zinc-box precipitate is fluxed and melted in the usual manner. The flux consists of 1 part soda, 2.2 parts borax glass and 0.1 part silica. The resulting bullion has a fineness of 924, of which 817 is silver. Actual

extraction for the first six months of operation was 92 per cent.

Cost of Power and Milling

The cost of electric power is 1.07 cents per kw-hr. A feature of the decantation department is the small amount of power required, one 10-hp. driving all machines as noted in the accompanying table.

Machinery Driven	DISTRIBUTION OF MOTORS	Hp.
Crusher.....		15
2 rolls, elevator, 2 trommels, plunger feeder.....		50
Tube-mill (variable speed).....		50
Dorr classifier.....		1
Compressor.....		10
Decantation system, 3 agitators, 5 thickeners, 5 diaphragm pumps, clarifier pump, return solution pump.....		10
Barren solution pump (2-in. Byron Jackson centrifugal, 25 ft. head).....		2
		138

The original estimate for cost of milling was \$3 per ton. The actual cost for a recent month was \$2.69 per ton, covering labor, superintendence, supplies and power.

Rochester Mill

An outline of the equipment and process used at the mill of the Rochester Mines Co., Rochester, Nevada, was first given in this journal, November, 1914. A flow-sheet of the proposed system was also shown, being in effect the same as given in Fig. 2 for the Pittsburgh-Dolores mill, except that six thickeners were provided instead of five. The three agitators were arranged in series between thickeners 1 and 2, and barren solution was added to thickener No. 4. The use of six thickeners instead of five was determined after finding by calculation that a lower dissolved loss could be thus obtained than by using only five machines and a double precipitation circuit. A further reason for the additional thickener was to guard against an excessive dissolved loss in case very high-grade ore might be treated.

A modification of the original flow-sheet was made in this case as with the Pittsburgh-Dolores, by introducing a decantation between agitators 2 and 3, thereby getting the benefit of a change of solution. The scheme as finally adopted is shown in Fig. 5. In this case, however, there were already enough thickeners installed to provide the usual four after agitation, which probably explains the lower dissolved loss obtained at this mill.

Rochester ore is valued chiefly for silver and a small amount of gold. It contains none of the ordinary base metals, such as copper, lead or zinc. Over 90 per cent is silica, and there is but 0.3 per cent of sulphur. The silver is reported to be in combination with sulphur, and with antimony of which the ore carries about 0.25 per cent.

The mill was originally designed to treat on a custom basis the ore produced by lessees in the Rochester mine. For that reason five 60-ton bins were constructed

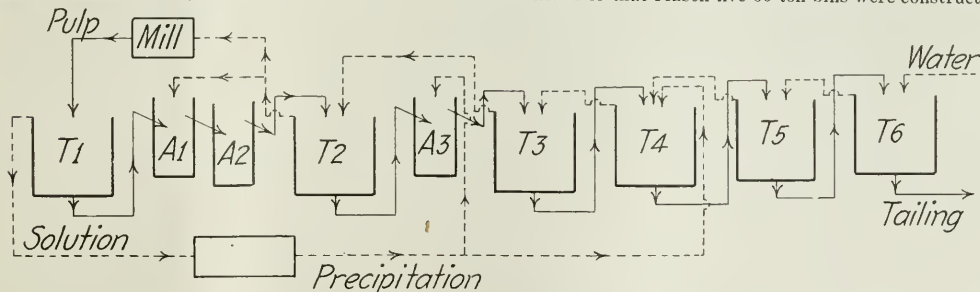


FIG. 5—SCHEME OF DECANTATION—ROCHESTER MILL

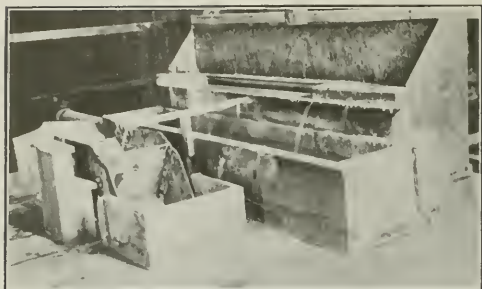


FIG. 6—TILTING-BOX SOLUTION METER—ROCHESTER MILL

and an elaborate sampling equipment installed. In the fall of 1915, however, the leasing system was discontinued and both mine and mill operated on company account.

With the completion of a spur from the Nevada Short Line, ore is now delivered to the mill bins by rail. From the bins it is trammed in $1\frac{1}{2}$ -ton cars to the sampling department where it is first weighed. The sampling equipment is of standard design and arrangement. There are three single Vezin samplers, each cutting one-tenth. The successive cuts are reduced in size and mixed before flowing to the next sampler, and the final cut gives one one-thousandth of the original lot.

The sampler reject is delivered to bins and thence to ten stamps. The latter weigh 1550 lb. and show a duty of twelve tons each per twenty-four hours, crushing through 6-mesh screen. Each battery of five stamps is driven by a 20-hp. back-gear motor, with special controller that makes it possible to start without previously having hung up the stamps. The ore is crushed in solution which is the overflow from No. 2 thickener, seven tons of solution being fed per ton of ore. The pulp flows to a Dorr duplex classifier placed between the two tube-mills which receive the coarse portion of the pulp and return the ground product again to the classifier. The classifier sand discharge is conveyed to the scoop feeders of the tube-mills by means of right and left-hand screws, and solution is added to give a moisture content of 38 per cent. Screen analyses of the classifier slime overflow will show about 90 per cent finer than 200-mesh. Komata linings and Danish pebbles are used in the tube-mills, both of which are driven by a single 100-hp. motor connected to the pinion shafts by silent chain drives with spring hubs and cut-off couplings.

Continuous Decantation of Slime

The scheme of decantation is shown in Fig. 5 which explains the process better than can be done by written description. The thickeners discharge a pulp containing from 44 per cent to 48 per cent moisture, except in the case of No. 6 which discharges a thicker pulp of about 42 per cent moisture. For agitation the pulp is diluted to 68 per cent moisture. Diaphragm pumps are used for the elevation of all pulps and the volume discharged is regulated by admitting air to the suction through pet cocks. In order to minimize the wear of diaphragms caused by rocking motion, the pumps are connected with overhead eccentric drives by means of 7-ft. rods which transmit motion to the diaphragms in an almost vertical direction.

Thickeners 2 to 6 inclusive are arranged on successively higher levels to permit the counter-flow of solution by gravity. The overflow of No. 1 is precipitated

and the barren solution is metered and returned to No. 4. The solution meter is of the tilting-box type shown in Fig. 6, connected with a counting device that registers each double throw of the box. The number of throws multiplied by a factor derived from the ratio of the full weir to the small launder leading to the tilting box gives the solution tonnage. The precipitation ratio is six tons of solution per ton of ore treated, being much higher than that for the Pittsburgh-Dolores mill on account of the higher grade of the ore. Water is introduced in the final thickener in amount necessary to counterbalance the loss of solution in the discharged tailing.

Prior to precipitation the solution is clarified in vacuum leaves, and at the zinc boxes a small amount of lead acetate solution is added. These precautions render precipitation highly efficient. As is customary with silver ores, the precipitate is not given an acid treatment before melting. It is dried, weighed, fluxed with soda, borax and fluorspar and melted in a Case oil-burning tilting crucible furnace. The resulting bullion has a fineness of 850 to 900 in silver and 5 to 6 in gold.

Small Loss of Dissolved Metal

Of the total silver dissolved, about 35 per cent goes into solution in the crushing and grinding apparatus, 55 per cent in the first two agitators and 10 per cent in the third. The strength of cyanide solution is kept up to 4 lb. KCN per ton by additions at No. 1 agitator. This solution is much stronger than that used at Pittsburgh-Dolores, and the mechanical loss also is higher, being about 1 lb. per ton. The loss of dissolved metal, however, is considerably lower, being reported by the management to be from 2 cents to 3 cents per ton. Lime consumption is high, varying with different lots of ore, but averaging 13 to 14 lb. per ton. Protective alkalinity is carried at $2\frac{1}{2}$ lb. CaO per ton. Lead acetate is added at No. 1 agitator and at No. 6 thickener.

The daily control of operations covers assays of pulps and solutions as previously shown for the Pittsburgh-Dolores mill. The value of mill feed is accurately determined by the automatic sample.

Comparison of Flow-Sheets

A comparison of the flow-sheets shown in Figs. 3 and 5 will show some variations in the counter-flow of solution. In one particular they are alike, viz., in dividing the agitation, giving part before and after an intermediate decantation. In the counterflow of solution the main differences are found in the return of barren solution to the system and in the way in which the overflows are diverted. In Fig. 3 all barren solution is returned to No. 4 thickener; in Fig. 5 there is a division of this solution, part going to No. 4 thickener and part to No. 3 agitator. The latter may be done in case it is found that dissolution is stimulated by the addition of fresh barren solution; otherwise the scheme in Fig. 3 may be followed, where part of No. 4 overflow is sent to No. 3 agitator. Again, in Fig. 3 the overflow from No. 3 thickener is used partly in the first agitator, while in Fig. 5 the overflow from No. 2 thickener is thus used.

The theoretical merits of different schemes can be computed from such known or determinable data as tonnage of ore, thickness of discharged slime, value dissolved per ton of ore, precipitation ratio, density of pulps in agitation, strength of cyanide solution, etc. The critical points are the loss of dissolved metal and mechanical loss of cyanide, and a flow-sheet should be adopted which shows the lowest combined value for these losses. The dissolved loss will be affected by the grade of the ore and the number of thickeners in use, and can be regulated in part by the amount of solution

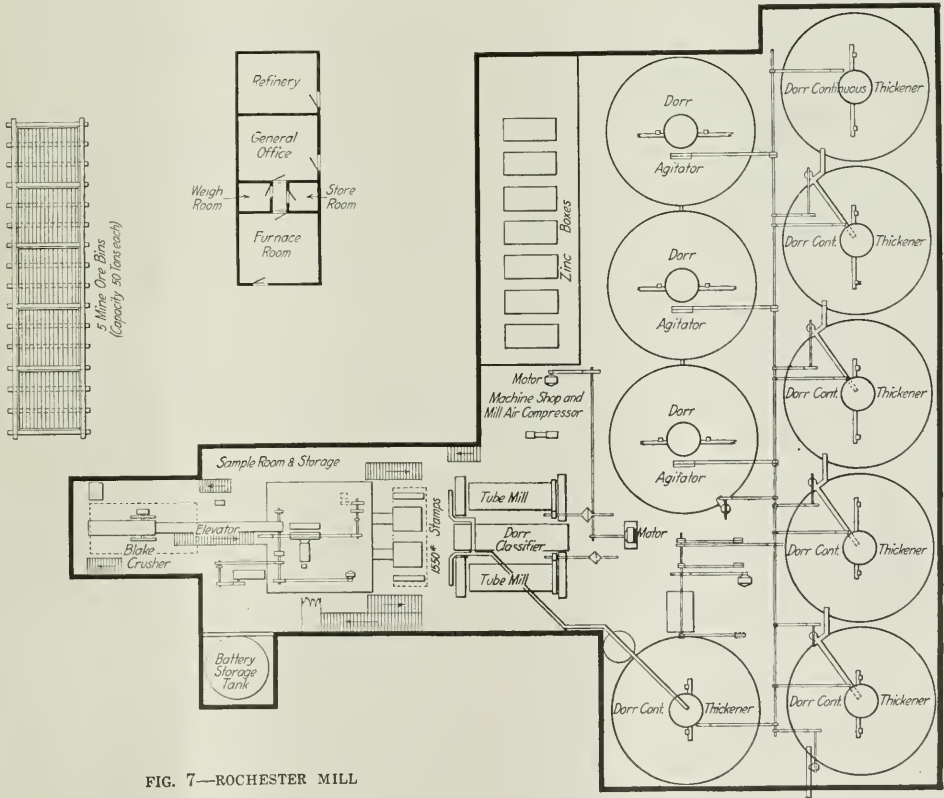
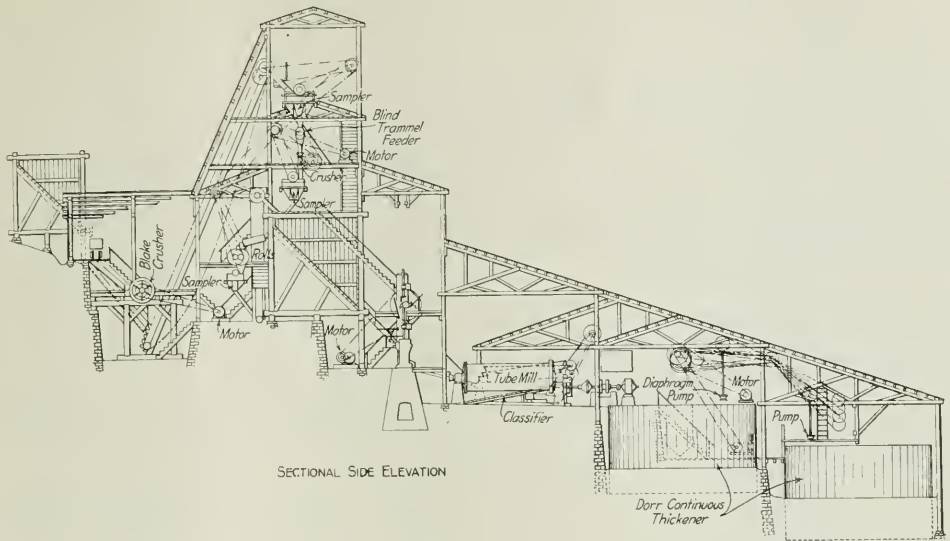


FIG. 7—ROCHESTER MILL

precipitated per ton of ore treated. Local conditions may determine the value of these variations, and a variety of counter-flows can be arranged to meet special needs. The settling area required per ton of solids and the density to which pulp can be thickened are important considerations.

For the information and data given on these two interesting plants we are indebted to Mr. E. J. Schrader, manager, and C. R. Olson, mill superintendent of the Pittsburgh-Dolores Mining Co.; and Mr. C. W. Poole, manager, J. C. Rasmussen, foreman, and W. C. Eminger, chemist, of the Rochester Mines Co.

Application and Earning Power of Chemistry in the Coal Mining Industry*

BY EDWIN M. CHANCE

During the last decade many conditions have been encountered that have materially increased the cost of the production of coal. As in most cases it has not been practicable to increase the selling price of such coal sufficiently to insure the necessary margin of profit, the mine management has been forced to avail itself of what

sales departments had felt convinced of the inferiority of this type of fuel and when complaints had been registered these complaints were given ready credence. Upon convincing the sales department of the quality of this type of fuel, but little difficulty was experienced in securing a ready market for it and it was even found possible to secure premiums for certain of these dull coals.

It is readily understandable that the only available means whereby a true appreciation of the quality of a fuel can be arrived at is by its chemical analysis or by a service test. The cost and unreliability of service tests have led to their general abandonment, hence the chemical examination of a fuel has been found to be perhaps the most ready and practicable method for determining its real position in the scale of usable fuels.

Now when we consider that in the past hundreds of thousands of tons of dull and unpromising looking coal have been gobbled at a positive cost to the coal producer, with the ever present danger of gob fires, that many other hundreds of thousands of tons of this material have been sent to the rock bank as refuse, and that because of the similarity of the specific gravities of the dull and bright coals, the difficulties and inefficiencies

TABLE I—AVERAGE COAL ANALYSES

Size	Test Number	Color of Ash	Moisture, Per Cent	Volatiles Matter, Per Cent	Fixed Carbon, Per Cent	Ash, Per Cent	Sulphur, Per Cent	Heating Value per Pound of Coal as Received, B.T.U.	Heating Value per Pound of Dry Coal in B.T.U.
Dull coal	C-502	Red	2.98	6.39	82.24	8.39	0.67	13,110	13,510
Bright coal	C-503	Red	3.70	5.67	81.16	9.47	0.71	12,890	13,380

might be termed unusual means that costs might be held at as low a figure as possible. The so-called efficiency engineer has been called upon, costly power plants have been built and machinery has been installed to replace manual labor wherever possible.

Another aid used recently to secure economies through the more intelligent production of coal, is the chemist. As the coal industry, barring the production of by-product coke, does not at once give evidence of its need of the services of the chemist, the writer will endeavor to point out a few of the services that this branch of the staff has been able to render.

COAL ANALYSIS.

The preparation of coal in the past has been carried on entirely upon an empirical basis, that is, the criterion adopted has been an ocular inspection. Unfortunately, the appearance of a coal and especially of an anthracite, has but little relation to its fuel value, and as long as coal is purchased for the heat that can be obtained from it by its combustion, the quantity of such heat that is purchased must be one of the principal desiderata in selecting or preparing a coal. Were coals purchased for use as bric-a-brac or for exhibition in museums it might be both wise and just to purchase them upon their appearance.

After 4 or 5 years of investigation the fact has been established that coals of very inferior appearance, and I now have special reference to anthracite, might and often did possess heating and burning properties superior to those possessed by bright coals which in the past had commanded considerable and uniform premiums in the market. This being the case the question arose as to whether the trade could be persuaded of this fact.

While at first some difficulty was experienced in establishing the quality of such dull coals, still it was found that the real obstacle to the sale of these materials in the past had been the fact that the coal producers' own

of coal preparation have been enormously increased by the attempted removal of this material, it will be seen how enormously profitable the utilization of this excellent fuel has been.

In order to give an adequate idea of the relative worth of the dull and bright material from the same veins, I will give in Table I the following average analyses:

These analyses are in both cases the average of a number of analyses of characteristic material of both types, and are in no sense selected. In the past this dull material, test No. C-502, has been condemned as bone. Thus by a systematic chemical investigation of the various steps in the preparation of coal undiscovered inefficiencies are revealed and their correction is made possible.

BOILER WATER.

In the efficient operation of boiler plants it is necessary to secure as soft and non-corrosive a boiler water as possible. While the most desirable method is to secure a supply of water that is naturally soft, still in the mining industry it is frequently necessary to use water that is both incrusting and corrosive. To meet these conditions a host of so-called boiler compounds has been foisted upon the unsuspecting mine manager. While certain of these compounds are worthless or of little value, others have considerable merit in special cases. Unfortunately, however, their use is indiscriminately recommended by the vendor, and a boiler compound that might prove efficient with waters of a certain type will prove of little value under different conditions. Moreover, the cost of these compounds is out of all proportion to their merit and a grave and positive risk is run of doing the boilers infinite damage by the indiscriminate use of such nostrums. I recall at this moment the case of one new boiler house equipment of several thousand horsepower capacity that was so damaged by 3 months' use of a highly recommended water softener, even though the water in this case was not very hard, that it required over a year and a half of patient and costly effort to put the plant back in a

*A paper to be presented at the Arizona meeting of the American Institute of Mining Engineers (September, 1916).

condition having the semblance of efficiency. Now a competent chemist can readily recommend a treatment for such boiler feed waters that will meet the requirements of the particular case in question both cheaply and efficiently.

By reason of inadequate storage facilities at many mines, a prolonged drought will occasionally require the use of mine water as boiler feed. The writer recalls one occasion when a large number of collieries of one company were operated with such feed water, containing in many cases as much as 10,000 parts per million of free sulphuric acid and 35,000 to 40,000 parts per million total acidity. These plants were operated successfully over a period of months with such feed water, though of course many difficulties arose and much care was required, while the surrounding coal-mining companies, not possessing expert chemical assistance, were in many cases required to cease operation.

LUBRICATION.

The subject of lubrication is one that has in the past been favored by the so-called efficiency expert. It is, therefore, with a sense of some diffidence that the writer approaches this subject. As conditions governing colliery lubrication are so very different from those governing the lubrication of the mill or industrial plant, it has been found that the lubrication secured by the use of lubricants recommended by the vendor has in the past been unsatisfactory and somewhat costly. Some years ago the writer conducted numerous field and laboratory tests in order to establish just which lubricants would best meet coal mine conditions. After these points had been well established an effort was made to go into the open market and, by specification, purchase the material desired.

While this plan was successful, still it was found that almost continual testing of the material supplied was required, as the bidders purchased their materials in the open market and hence there was little or no uniformity of supply. Those bidders not purchasing oils in this way were, in many cases, refiners handling such a diversity of crudes that practically the same complaints arose. It was found that the independent refiners of Pennsylvania petroleum produced the lubricants required, and since the materials were produced by them and their range of production was rather limited, little difficulty was encountered in securing uniform products from them. Moreover, by concentrating the purchases for a number of coal producers upon one refinery, it has been possible to secure most advantageous prices while at the same time the quality of materials supplied is directed by the purchaser and not by the vendor.

In other words, the oil to meet any special condition is purchased from the refiner without consulting him as to its use. Hence there is little or no probability of his attempting to substitute a material that he may consider almost as suitable, as he has no knowledge of the use to which the material in question is to be put. It is an axiom that given a maximum price that a purchaser will pay, the average vendor will endeavor to supply the material that costs him the least but that will meet the condition in question. In purchasing lubricants as indicated above this condition does not arise, as the oil for the purpose in question is selected without considering its price, and further, since the vendor is not consulted in the matter, the best oil that can possibly be obtained for the particular purpose is secured.

It may seem that the cost of such a procedure would be prohibitive, and this would be the case were these materials purchased at the scale of prices that usually obtains. By means of the co-operation mentioned above,

however, prices have been secured that are so advantageous that the highest grade of product that it is possible to secure, irrespective of price, is generally purchased at a lower price than the product of mediocre quality that was formerly used. In this way the actual first cost of lubrication has been reduced from 30 to 50 per cent, while the actual efficiency, though less readily determinable, of the lubrication secured has been greatly increased.

MINE FIRES.

The chemist has been found to be almost indispensable where a mine fire is being extinguished by cutting off its air supply, for the chemical analysis of the air from the fire zone makes it possible to form an intelligent opinion of the progress of the extinction and the airtightness of the dams or fire walls built to control the fire.

Many more instances than those briefly touched upon might be quoted and those that have been quoted might be developed in greater detail. Such a dissertation, however, would be burdensome and would fall without the purpose of these notes.

Wilkes Barre, Pa.

The Electrolytic Determination of Copper in Copper-Manganese

BY EMIL D. KOEPPING

When determining copper by electrolysis in the presence of large amounts of manganese, the simultaneous deposition of copper at the cathode and manganese at the anode affords at best uncertain results. Too, the determination of manganese by electrolysis lacks interest. For these reasons the work described in this paper deals wholly with methods of depositing copper which also prevent the deposition of manganese.

So far as I have been able to find out only two methods of accomplishing this have been advanced. Classen¹ recommends the use of a large excess of nitric acid in the electrolyte, while E. F. Smith² mentions the use of a phosphoric acid solution. The objection to Classen's method is the ever-present liability of losing some of the copper by solution in the strong nitric acid during removal of the electrode. The method given in the old edition of Smith results in bad-colored deposits, as was expected.

A hint given by McCay³ in his paper on the separation of copper and lead from antimony and tin was developed and, with slight modifications, yielded good results.

For convenience the methods of accomplishing the purpose have been divided into two general classes:

I. Soluble anodes.

II. Special electrolytes.

In all experiments where stationary electrodes were used the current was 3 amp. at 3 volts, and where the rotating electrode was employed the current used was 9 amp. at 3 volts. The volume of electrolyte was in all cases 125 c.c. The results recorded under each experiment are typical of those obtained.

I. Soluble Anodes

(a) IRON ANODE

It is well known that copper can be determined in the presence of large amounts of iron by several means. A simple way is to limit the quantity of nitric acid to 1 c.c. in 125 c.c. of electrolyte. The solution of the salts (sulphates or nitrates) was first neutralized with am-

¹Classen-Hall, Quant. Anal. by Electrolysis (1913), p. 281.

²E. F. Smith, Electro-Chemical Analysis (1890), p. 92.

³L. W. McCay, J. Amer. Chem. Soc., 36, 11, p. 2375.

monia and then acidified with 1 c.c. of sulphuric acid and 1 c.c. of nitric acid.

1. Cu present	Cu found	Error	Mn present
0.3975	0.3963	— 0.0012	0.0978

Stationary Pt gauze cathode.

Stationary, pure iron, spiral anode.

2. Cu present	Cu found	Error	Mn present
0.3500	0.3484	— 0.0016	0.1500

Rotating copper gauze cathode.

Stationary, lattice form, piano-wire anode.

3. Cu present	Cu found	Error	Mn present
0.3500	0.3491	— 0.0009	0.1500

Rotating copper gauze cathode.

Stationary, lattice form, piano-wire anode.

(b) NICKEL ANODE*

The solution to be electrolyzed (sulphates or nitrates) was neutralized with ammonia and then acidified with 2 c.c. of nitric acid and 1 c.c. of sulphuric acid and diluted to 125 c.c. in each case.

1. Cu present	Cu found	Error	Mn present
0.3860	0.3853	— 0.0007	0.1119

Stationary Pt gauze cathode.

Stationary heavy nickel-wire anode.

2. Cu present	Cu found	Error	Mn present
0.3500	0.3494	— 0.0006	0.1500

Rotating copper gauze cathode.

Stationary heavy nickel-wire anode.

3. Cu present	Cu found	Error	Mn present
0.3500	0.3494	— 0.0006	0.1500

Rotating copper gauze cathode.

Stationary heavy nickel-wire anode.

4. Cu present	Cu found	Error	Mn present
0.3860	0.3855	— 0.0005	0.1119

Stationary copper gauze cathode.

Rotating nickel-paddle anode.

(c) ZINC ANODE

The solution for electrolysis was prepared in the same way as were those under (b).

1. Cu present	Cu found	Error	Mn present
0.3500	0.3412	— 0.0088	0.1500

Rotating copper gauze cathode.

Stationary C.P. zinc-rod anode.

Some copper separated on the anode in a loosely adherent form. Most of this redissolved, but some did not. Zinc sulphate formed and adhered to the anode. A pure nitric acid electrolyte might overcome these objections but was not tried.

(d) ALUMINIUM ANODE

The solution was prepared in the same manner as under (b).

1. Cu present	Cu found	Error	Mn present
0.3500	0.3484	— 0.0016	0.1500

Rotating copper gauze cathode.

Pure aluminium-wire anode.

(e) CADMIUM ANODE

Only a qualitative experiment was made for the cadmium seemed to be open to the same objections as the zinc anode.

II. Special Electrolytes

(a) Electrolyte containing 25 c.c. conc. nitric acid.

1. Cu present	Cu found	Error	Mn present
0.3525	0.3520	— 0.0005	0.1500

Rotating copper gauze cathode.

Stationary lattice form Pt anode.

(b) Electrolyte containing sulphuric, nitric and hydrofluoric acids.

The solution of the metals after neutralizing with ammonia was acidified with 1 c.c. of sulphuric acid, 2 c.c. of nitric acid, and 1 to 2 c.c. of 48 per cent hydrofluoric acid.

1. Cu present	Cu found	Error	Mn present
0.3525	0.3522	— 0.0003	0.1500

Stationary platinum gauze cathode.

Stationary Pt spiral anode.

2. Cu present	Cu found	Error	Mn present
0.3525	0.3521	— 0.0004	0.1500

Stationary Pt gauze cathode.

Stationary Pt spiral anode.

3. Cu present	Cu found	Error	Mn present
0.3860	0.3857	— 0.0003	0.1119

Stationary Pt gauze cathode.

Stationary Pt spiral anode.

(c) Electrolyte containing sulphuric, nitric and phosphoric acids.

The solution of the metals was neutralized with ammonia and then acidified with 1 c.c. of sulphuric, 2 c.c. of nitric and 5 c.c. of phosphoric acid.

1. Cu present	Cu found	Error	Mn present
0.3860	0.3856	— 0.0004	0.1119

Stationary Pt gauze cathode.

Stationary Pt spiral anode.

2. Cu present	Cu found	Error	Mn present
0.3975	0.3973	— 0.0002	0.0978

Stationary Pt gauze cathode.

Stationary Pt spiral anode.

3. Cu present	Cu found	Error	Mn present
0.3500	0.3495	— 0.0005	0.1500

Stationary Pt gauze cathode.

Stationary Pt spiral anode.

CONCLUSIONS

The results obtained with the nickel anode are perhaps sufficiently accurate for rapid control work. The results obtained with the hydrofluoric acid electrolyte and with the phosphoric acid electrolyte, which also contains free nitric and sulphuric acids, leave little to be desired. Glass beakers can be used with the hydrofluoric acid electrolyte without difficulty.

Lockport, N. Y.

Russian Chemical Industries

According to information received from Russia the *Chemical Trade Journal* (London) says the Industrial Mobilization Committee of Moscow has decided that there is no occasion to erect new works for the production of sulphuric acid, but that the output of the existing works should be increased, particularly in the case of oleum and oil of vitriol. The committee expresses the opinion that with the object of avoiding an exaggerated rise in the price of and speculation in sulphuric acid, after the requirements of the army have been satisfied, the whole of the available quantity then remaining should be placed at the disposal of the committee for distribution among private consumers at a uniform price.

The discovery of deposits of saltpetre in the Altai was reported a few months ago. An expedition is now being formed to set out to investigate the deposits. It is also proposed to make further researches and new borings for saltpetre near the Iessentouki station.

In the case of the production of soap the Committee of the Union of Zemstvos of the Southwest of Russia has rented the Seidel Works near Kieff for the manufacture of soap. It is possible to produce 5000 poods per month, of which the fatty materials would represent about 60 per cent (1 pood = 36 pounds).

The question of the deposits of sulphur in the district of Kerch is to form the subject of a report by the authorities of Simferopol to the president of the Government Committee on Industrial Mobilization, with the

*When using commercial "pure" nickel it is necessary to determine the copper contents and average consumption of nickel for the time and current density being used and to subtract the "copper value" of this amount of nickel from the weight of deposited copper.

object of the adoption of measures for working the deposits.

The prices of chemical products at Petrograd are reported to have again increased all round, and no transactions are taking place in certain products, the quotations for which are purely nominal. This is particularly the case with borax in crystals, arsenic in powder and lump, ammonia salts, sulphur, etc.

Burdening the Blast Furnace

BY J. E. JOHNSON, JR.

This is the technical name for regulating the different materials used in the charge and the proportions of each to bring about, first, the successful operation of the furnace; second, the production of the kind of iron desired.

The quality of the iron depends principally upon its content of six elements—silicon, sulphur, phosphorus, manganese, carbon and oxygen, these being given approximately in the order of their importance as effecting the general character of the product. Some of these elements come from one portion of the charge and some from others.

We must, therefore, consider the burdening of the furnace from two points of view, first, that of the raw materials charged, which determines the quantities of foreign substances entering the furnace; second, from the point of view of the iron to be made. The content of the iron in the ingredients mentioned varies very widely, according to the purpose for which it is intended. The different varieties of iron and their contents in the different metalloids will be discussed later in an article on "Product." We will, therefore, consider here only the methods of controlling the quantities of the different elements mentioned above which enter the iron.

Silicon Control

To produce the desired silicon percentages we have two principal means which may be used singly or in combination. These factors are in the order of their importance: First, temperature, and, second, slag composition.

Since the temperature of reduction of silicon is far higher than that of iron and since the affinity of the latter for silicon diminishes as the percentage of the silicon in the iron increases, the temperature necessary to secure increasing percentages of silicon rises steadily as the silicon rises above 1 per cent. (Below that point in coke practice other factors come in.) Therefore, as we desire to raise the silicon we must first of all generate more hearth heat; so unless we can increase the blast temperature we must use more fuel.

Second, we must control the silicon entering the iron to a very large extent by the character of the slag which we use. With a given temperature of slag the limier one will have the stronger affinity for the silica as such, and will, therefore, carry off a larger percentage of it in its unreduced condition, while if the temperature remains the same, as the lime in the slag is lowered the equilibrium between the iron and the slag is shifted toward the iron and more silica is reduced to silicon and passes into the iron.

It will be noted that pains have been taken to specify that the temperature be the same, and this is a very important stipulation because generally in coke practice the temperature of the slag rises with its content of lime, and, as I have before explained, it is the temperature of the slag which controls that of the iron, the slag being less fusible and acting as a retardant in the bosh, down through which the iron must pass on its way into the hearth. Therefore, the more infusible the

slag the higher the temperature of the iron, the stronger the reducing action of the coke on the silica, and the higher must be the silicon in the iron to reach equilibrium with the silica in the slag.

This action is so important that it is sometimes impossible to obtain the required amount of silicon in the iron without increasing the lime far beyond what is necessary for desulphurization in order to raise the slag and through it the iron to the required temperature. In other words, there are actual conditions under which increasing the lime *increases* the silicon in the iron, the temperature effect of the increase more than offsetting its chemical effect.

In the article on slag it was shown that alumina had a decided effect in raising the free-running temperature of the slag without causing any increase in the basicity of the slag. The addition of alumina, therefore, gives us the higher iron temperature desired without increasing the affinity of the slag for the silica and so withdrawing it from the iron. For this reason the possibility of the use of alumina in considerable quantities in foundry iron slags was suggested in the paper quoted therein, and I have since come across statements in literature on the subject and from furnace operators confirming the correctness of this conclusion. My own experience does not cover the point exactly. The model showing the melting temperatures of lime, silica and alumina mixtures shows that the curve representing the effect of alumina alone is by no means a smooth and regular one, and it is, therefore, to be expected that a given increase of alumina would have different effects in different portions of its range.

The Effect of Magnesia in the Slag

The fundamental slag is composed of silica, lime, alumina. The effect of an addition of magnesia follows the universal law that an addition to the number of bases lowers the fusion point of the whole. Magnesia is probably not more active, weight for weight, than lime, although on the basis of its atomic weight, or the molecular weight of its oxide, 40 against 56 for lime, it should be 1.4 times more active. It does, however, have the effect of thinning the slag very materially and this is of enormous value, particularly in the manufacture of low-silicon irons; in exactly the opposite way from that in which alumina is probably of value for the manufacture of high-silicon ones. It lowers the melting point without altering the basicity of the slag.

This is of particular importance in the manufacture of iron for the basic process, whether Bessemer or open hearth, in both of which silicon is objectionable because the silica resulting from its oxidation attacks the basic (lime or magnesia) lining of the vessel and rapidly eats it away.

In coke practice it is not difficult to keep the silicon in the iron down to about 1 per cent, simply by adding more burden and thus keeping the hearth temperature too low to permit more silicon than this to enter the iron, while the furnace still remains hot enough to obtain good desulphurization. Below this point, however, difficulties begin to appear because if the hearth temperature be kept down for the production of a lower silicon than this with the same kind of slag, the point having been reached at which the slag is approximately saturated with that element for the given conditions, the surplus begins to pass into the iron. We must, therefore, take some step to prevent this action. The obvious one is to increase the lime in the slag, but this has the effect of increasing its temperature simultaneously, which in turn requires additional fuel, and these two factors are the very ones required to raise the

silicon, whereas what we are trying to do is to lower it.

We must, therefore, find some method of increasing the basicity of the slag without increasing its temperature. This method, and practically the only one available for the purpose in ordinary practice, is to substitute magnesia for a portion of the lime. The famous experiments of the Swedish investigator, Akerman, while not directly applicable because he determined the softening point rather than the free-running temperature of the slags, indicated that the most fusible slag was to be found with about two parts of lime to one of magnesia, and while the data of furnace operation are seldom or never accurate enough to determine points like this with mathematical accuracy, such data as we have seems to bear out the correctness of this ratio for practice.

Control of Sulphur

This is the element which indirectly produces most of the difficulties in the operation of the blast furnace. Charcoal furnaces have the vast advantage of a fuel almost free from sulphur, and unless this element be introduced with the ore or flux (which should never be done in charcoal practice because it vitiates the advantage of the fuel) there is so little of the element present that even a relatively very acid slag takes out nearly all of it.

In coke practice the conditions are very different; there is always sulphur in considerable amount in the fuel. There are exceptional cokes containing 0.5 per cent or even less of this element, and considerable quantities containing from 0.5 to 1 per cent, but a large and increasing percentage of all the coke now used in the district served by Lake ores runs from 1 per cent to 1.4 per cent in sulphur, and in some other districts the sulphur may even go higher than this. In a rough way about 1 lb. of coke is required to make a pound of iron, and as the sulphur limit on practically all iron is under 0.06 per cent it is evident that at least fifteen-sixteenths of the total sulphur charge must be removed by the slag, generally more.

There are two routes by which the sulphur can leave the furnace without contaminating the iron. It can be volatilized and passed off with the top gases or it can be fixed and carried out by the slag. In general it probably follows both routes to some extent, but the greater portion always goes out in the slag.

Very little is known as to the amount of sulphur which can be driven off with the top gases. The subject has been very generally neglected, but Mr. James Bell, superintendent of furnaces at the Algoma Steel Works, having had to use an ore containing a considerable percentage of sulphur, has made some very interesting investigations and has found that as much as 35 per cent of the total sulphur may be volatilized and pass off with the gas, and so not require to pass through the hearth at all.

The principal condition for bringing about this end he has found to be that the slag shall be as acid as the conditions permit; as the slag becomes more basic more and more of the sulphur is fixed by it and prevented from volatilizing. From the point of fuel economy there is absolutely no doubt of the desirability of keeping the sulphur out of the hearth altogether rather than permitting it to enter and then eliminating it.

That the sulphur has no ill effect on the gas for use under boilers and in stoves can be stated positively, for the total amount present in that gas with the maximum degree of volatilization mentioned (35 per cent) is but a small fraction of that in the products of combustion of many coals in successful use under boilers. The presence of sulphur does not seem to injure the gas

even for gas engines, as the plant mentioned is equipped with these and no trouble from corrosion has arisen after several years' use.

For keeping out of the iron the sulphur which reaches the hearth we have available, as described in the article on chemical principles of the blast furnace, five possible methods: increasing the lime content of the slag, increasing its volume, increasing its temperature, increasing its fluidity, and increasing its manganese content above those required in the absence of sulphur. Some of these methods assist one another, while others are in direct conflict. The best result must be obtained by a proper balance among all, for the determination of which there is no mathematical equation; in this, as in other departments of furnace operation, there is no substitute for horse sense.

By increasing the lime, leaving out for the present all question of temperature, we obviously provide additional free base, and we can see that if the slag was in a comparative state of equilibrium before, both the bases and the silica being reasonably well satisfied, it is obvious that this additional base will hunt some other acid in order to satisfy itself, and the only one available is the sulphur in the coke. Of course, as a matter of fact, the addition of lime simply alters the ratio of the lime to the silica, and so modifies the slag, but this alters the equilibrium, and if we conceive that the amounts of sulphur passing into the iron and into the slag were in equilibrium before, it is obvious that this equilibrium has shifted toward the slag, and that more thereafter must pass into the latter.

Increasing the volume of the slag diminishes the concentration of the sulphur in it, and similarly alters the equilibrium of the slag in regard to this element. Or, to put the matter in a still simpler way, if a given amount of slag absorbs and carries off a given amount of sulphur under certain conditions, then an increased volume of slag will dispose of a proportionally increased quantity of sulphur under the same conditions. Of course, the effect of the addition of lime is to increase the slag volume and we obtain the benefit of a slight increase in volume whenever we increase the lime, but this is generally less than 5 per cent. Where an excessive amount of sulphur must be eliminated, it is sometimes necessary deliberately to add to the burden slag-forming materials, in general silica, and the necessary lime to flux them, so as to make a substantial increase in slag volume.

Here again we have to meet a condition for which theory indicates qualitatively but not quantitatively the method to be followed. By adding lime we increase the free base, increase the slag volume, and increase the fusion temperature of the slag, all of which have a very strongly desulphurizing effect. But the more limey slag brings more sulphur into the hearth to be eliminated, while the effect of increasing the temperature of the slag is to increase the critical temperature of the furnace and thereby materially increase its fuel consumption. If, on the other hand, we add to the burden silica and sufficient lime only to keep the ratio of the two the same as before we must make in general a much larger addition to the slag volume to accomplish the desired desulphurization, but we do not increase the critical temperature; we do, however, increase the requirements for hearth heat to melt the additional slag. Both of these methods of increasing the removal of sulphur, therefore, have the result of increasing the fuel consumption.

I do not believe it is possible to figure out in advance which one of these is the most economical, or whether the combination of the two is more economical than either. The latter is probably true, but the final de-

cision can be correctly made only on the basis of experiment on the furnace itself.

We have seen that the first three methods of increasing desulphurization work together. That is, that an addition of lime meets all three conditions to some extent. But we have the fourth method, that of increasing the fluidity of the slag; and this is extremely important. I have already described how certain slags so limey as to "slack" when cold, if the hose was turned on them, fail utterly to give satisfactory desulphurization, partly because they raise the critical temperature so high that but little hearth heat is left above it, but very largely also because the slags are too stiff and pasty to mingle intimately with the coke, and so catch the sulphur as it is evolved by the combustion of the latter.

It is evident then that this need for fluidity sets a definite limit which we may not pass in adding lime for the utilization of our first three methods. On the other hand, we have no commercial method whereby we can increase the fluidity of the slag without diminishing its liminess, except the substitution of magnesia for part of the lime, as already described, and the addition of manganese within narrow limits. So for commercial work we must be satisfied to secure a compromise between fluidity, high temperature, and basicity. In cases of serious trouble the addition of fluorspar might doubtless be beneficial because its effect in lowering the free-running temperature of slags is extremely marked, but this is a subject which may be better discussed in a later article, it being impossible for commercial reasons to use fluorspar in normal operation.

Manganese has a much higher affinity for sulphur than has iron and the manganese sulphide formed is dissolved in the slag instead of the iron as the iron sulphide is. It is probable also that the presence of manganese oxide renders the slag more fluid just as oxide of iron does, hence the addition of manganese to the charge is beneficial to both the sulphur-carrying powers of the slag, basicity and fluidity, whereas lime is beneficial to one and highly detrimental to the other. It is, of course, out of the question to add manganese oxide to the charge as a flux, but a wide latitude of manganese contents is often to be found in ores of the same cost, and in such cases it is distinctly helpful to add manganese to the charge up to the limit set by the amount desired in the iron.

For economical desulphurization then we must have a reasonable volume of fluid slag, not too limey and preferably carrying some manganese. If the quantity of sulphur to be eliminated exceeds the sulphur-carrying capacity under these conditions, we must then go to increasing lime and increasing slag temperature or increasing slag volume or both, but in any event economy must be sacrificed.

We have then two methods whereby iron low in sulphur and also low in silicon can be produced. First: we can increase the lime, increase the blast temperature if possible, and increase the coke enough to offset the rapid rise of the critical temperature resulting from the more infusible slag. The hearth heat decreases in spite of the increased blast temperature and increased coke because the critical temperature increases faster than the coke ratio. All of this tends to make the iron physically hotter but chemically colder, that is to say, to lower the silica, and this result is of course greatly assisted by the hot excessively basic slag produced with its huge affinity for silicon. The result of making low-silicon iron by this means is to increase the fuel consumption. That is to say, it requires more coke and considerably more limestone to make an iron with 0.75 silicon than it does to make one with 1.50

silicon, because, as stated above, the critical temperature rises rapidly, with the consequences pointed out in the article on thermal principles.

On the other hand, we can work on the plan of making the slag just as fluid as possible, consistent with desulphurization, and then pile on burden, that is, additional ore, until the hearth heat per unit of iron is so reduced that the silicon can not rise above the limit desired.

The result of this method of operation is to reduce the fuel consumption, so that working on this basis it requires less fuel to make an iron of 0.75 silicon than it does to make one of 1.50, but it requires more careful furnace work and involves running on a smaller margin of safety.

When it comes to making irons of high silicon beyond 3 per cent we have no recourse but to increase the fuel ratio so that the hearth heat per unit of iron being high, a surplus is left, a part of which expends itself in reducing more silica. Of course, the surplus is not large because the increase in hearth heat is not really very rapid. The additional fuel is spent in trying to keep pace with the rise in the critical temperature necessary.

It is quite probable that above a certain point, probably four or five per cent silicon, the critical temperature ceases to be the free-running temperature of the slag and becomes simply the temperature of the iron at which it will absorb the required percentage of silicon. Here then we are at the disadvantage of no longer having the cinder to act as a retardant and assist in the work of heating the iron to the desired temperature by delaying its descent, and the efficiency with which we utilize the heat produced in these furnaces is therefore decidedly lower than any furnace on the ordinary range of silica. It is because we are without this retardant action that the hearths of furnaces on high-silicon iron are made smaller than those for steel-making and other moderate silicon iron. In order to obtain the heating of the iron desired we must give it a more intense and intimate contact with the hot gases as they arise from the hearth and this can obviously be done by narrowing the hearth and the base of bosh, in which this action takes place.

Above 15 per cent silicon the temperature necessary becomes so high that there is little or no hearth heat to be obtained above it and it becomes commercially impracticable to make higher silicon irons even by considerable further increases in the coke ratio.

In the range from 1 per cent to 3 per cent silicon, we change the product of the furnace from one silicon content to another by changing the burden and leave the slag ratio almost unchanged.

Manganese Control

Our control of manganese is not as complete as it is of some of the other elements. It is practically impossible to throw much more than about 80 per cent of the total into the iron except perhaps at low percentages, under 2 or 3 per cent; when, owing to the high solution power of the iron, a somewhat greater percentage of the total manganese charged may, under favorable circumstances, enter the iron. On the other hand, we cannot in practice secure its complete elimination, because with the furnace in proper working condition a certain percentage of the total amount charged always enters the iron in spite of our best efforts. With a furnace working cold, making white iron, and a thin scouring cinder, practically all the manganese is carried off, but as it is impracticable to operate a furnace this way commercially this fact is of no

real value in manganese control. It is safe to say that the lower limit of the manganese entering the iron in ordinary good practice is about one-third of the amount charged, and that in a general way the ordinary range of manganese content in the iron comprises from one-third to two-thirds of the amount charged.

Manganese is very much more active chemically than iron and therefore has a much greater tendency to act as a base, forming manganese silicate, and passing out in the slag. Its temperature of reduction, and also its heat of reduction, are considerably higher than that of iron, therefore in order to throw the maximum percentage into the iron the furnace must be very hot and the silica must be as completely satisfied as possible. Both these results are accomplished by making a very limey slag, the lime is a stronger base than the manganese and therefore when present in excess has a strong tendency to prevent the manganese from obtaining any silica with which to combine, though this action is not absolutely complete. On the other hand, as we have already seen, the effect of calcareous slags is to raise the temperature of the furnace, provided of course sufficient fuel be charged to supply the quantity of hearth heat required above this high temperature. In order to throw the manganese into the iron therefore we must use a light burden and a very limey slag. This tends to prevent the loss of manganese in the slag and to reduce it to the metallic condition, but the high heat here brings in a bad effect when high percentages of manganese are present, as the manganese vaporizes and for some reason does not recondense in the upper regions of the furnace, but passes out of the gas as a dense yellow fume. Furnaces working on ferromanganese can be recognized by their smoke for miles.

When it is desired to lower the manganese in the iron the opposite procedure must be followed. Lime in the slag is reduced to the lowest possible limits consistent with desulphurization so as to make a thin fluid slag, to keep down the hearth temperature, and to leave some silica relatively free so that it can combine with the manganese oxide and slag it off.

We have here those conditions of gradually shifting equilibrium of which I have so often had occasion to speak. The iron itself has an affinity for manganese on one side, while the slag, especially a siliceous slag, has an affinity for it on the other. High temperature shifts this equilibrium toward the iron side, but no conditions at our command enable us to reach either end of the scale. The affinity of the iron for the manganese never completely triumphs over that of the slag so as to absorb it all into the iron, while on the other hand it never falls so low that all the manganese can pass into the cinder under normal working conditions.

We have, however, a further means of controlling manganese to some extent. I have spoken of the action of a scouring slag, and we can to a certain extent produce such a condition in a normal working furnace by charging a certain amount of material which has a tendency to produce a scouring slag, such a material for instance as mill cinder. It is well known that metallic manganese will reduce iron from slag, the oxide of manganese produced by the reduction replacing the iron oxide in the slag. The effect of thus producing a scouring slag is to supply a certain amount of unreduced iron on which the manganese in the iron can work as it passes through the slag into the hearth, and by this action the manganese is lowered materially. By the use of this expedient in charcoal practice I have been able to produce iron on low manganese specifications that could not be made from the ores available

without the addition of mill cinder even with the most acid cinder we could use.

Phosphorus Control

This is extremely simple in one way because we know that when the furnace is operating properly 100 per cent of the phosphorus charged will enter the iron. As explained in the article on chemical principles a very scouring slag, such as made by a furnace completely deranged carries off as much as 10 per cent or even more of the total phosphorus charged, but while this is a matter of some scientific interest it has no bearing whatever on the question of burdening the furnace for commercial purposes.

In order, therefore, to produce an iron containing a given amount of phosphorus we must provide a charge which contains just that amount. This sounds simple enough, but when the phosphorus limits desired are very low it becomes a matter of great difficulty to secure raw materials so free from that element that the iron will not contain more than the amount specified. In the case of specially low-phosphorus or extra Bessemer iron described later, with specifications of 0.035 and under, this difficulty becomes extreme. For instance, if two tons of ore, one ton of coke, and half a ton of limestone be required per ton of iron, and each of these materials contains one-hundredth of 1 per cent, the resulting product will contain the maximum permissible amount of phosphorus, 0.035 per cent. Such raw materials are extremely rare and in consequence iron of this kind commands a premium of several dollars per ton over iron exactly analogous in other respects but a trifle higher in phosphorus.

The same condition holds good in regard to the Bessemer specification, but of course in a much less degree, because both on the theory of probability and as an actual fact the supply of a material of a given degree of purity increases very rapidly as the purity required diminishes, so that many thousand times as much ore are available for making iron of 0.09 phosphorus as are available for making it of 0.035.

On the other hand, the amount within the wider limit is a relatively small proportion of the total amount of iron ore in the world, and therefore Bessemer iron commands a premium of from one to two dollars per ton and Bessemer ore suitable for making it commands a corresponding premium diminishing as the use of Bessemer steel decreases.

The same conditions are true in regard to supplies of coke, but not to the same extent. Cokes contain as a general thing only small percentages of phosphorus, and while some premium is paid for cokes extraordinarily low in this element, it is small in comparison with the premium on low-phosphorus ores.

Turning now to the other end of the scale, there are produced great tonnages of iron in which the phosphorus must not be below certain limits, in ordinary foundry irons about 0.5 per cent, the production of this in a district of low-phosphorus ores, high-phosphorus material sometimes commands a premium. Extra-high-phosphorus ores are often hauled hundreds of miles for admixture with those of lower phosphorus when foundry or other high-phosphorus iron is desired, and in very many cases the phosphorus which the steel maker has been at such pains to eliminate from one iron to convert it into steel is charged back into the furnace in the form of open-hearth slag so as to increase the phosphorus in another iron. In some cases even phosphate rock is used to give the desired phosphorus, and one resourceful furnace-man in the Northwest, running a charcoal furnace on rather low-phosphorus ores, when he received an order for high-

phosphorus iron, produced it by collecting the beef bones from the surrounding lumber camps and charging them as flux.

For certain purposes steel must contain more phosphorus than is left in it by the basic open-hearth process and such steel is rephosphorized by the use of ferrophosphorus, a special product made at only one blast furnace in this country. The phosphorus in this material ranges from about 17 to 18 per cent, the raw materials being iron ore and phosphate rock, with silica as flux for the excess lime of the phosphate.

Control of Carbon

We know very little of the general subject of the carbon contents of the different kinds of iron and the obvious corollary is that we know very little in detail about methods for its control, but in a general way we do know that a large quantity of carbon in the hearth and high hearth temperature contribute to high carbon, and the opposite conditions to low carbon.

I shall later point out that an excess of hearth heat, which of course in itself tends to produce higher hearth temperature than would otherwise occur, tends to high carbonization, and a cold working furnace hearth on the other hand tends to lower carbon. In a subsequent article I shall describe a certain variety of charcoal irons, known as spotted irons, whose undesirable characteristics come from high carbon, and it was believed in the charcoal business before the cause of the iron's peculiarities was known, that this iron is produced by too small a slag volume and a limey slag. The small slag volume tends to leave an excess of hearth heat, and the limey slag tends to a high temperature, while the deficiency of heat in the shaft of these furnaces results in a comparatively large quantity of fuel in the hearth. Hence these conditions all make for high temperature, an excess of hearth heat, and a large quantity of carbon in the hearth. These are the three principal factors tending to high carbonization. This shows that there is close agreement between a rather vague belief developed, almost as tradition, through long years of practice and the fundamental principles set forth, is very good.

On the other hand, charcoal furnaces which work with low blast temperature, very fusible slags, and quite large slag volume, sometimes produce irons very low in carbon, down to 3.4 or the like, and this also is in agreement with the principles above laid down.

In coke irons the possibilities of variations in the conditions are less, and the limits within which carbon varies are correspondingly narrower, but I have been advised by Mr. John S. Kennedy, who has paid much attention to this subject, that by using a rather irreducible ore with a limey slag, and comparatively high fuel, he was able to maintain the carbon above 4 per cent even with silicon up to 3 per cent, although that percentage of the latter element is ordinarily high enough to cause some reduction in the carbon. This is in line, in a general way, with the principle set forth above and with charcoal practice. On the same basis one would expect a coke furnace running with a moderate volume of fusible slag, and on a comparatively fusible ore, to produce irons low in carbon, and while I have no exact data on this subject I believe it to be a fact that the irons made in Virginia on low-alumina fusible slags, and approximately under the conditions outlined, are lower in carbon than any other coke irons made in this country.

Oxygen Control

Definite knowledge of the quantity of oxygen in cast iron only dates back two or three years, and the views

set forth on its effects in a later chapter are by no means universally accepted, but their correctness has been demonstrated by a vast mass of facts, and they are accepted by some of the highest authorities, so that they will be considered as established.

Owing to the necessity of treating the subject of oxygen as a whole on account of its novelty, most of the data we have concerning oxygen control are included in the subsequent article on products, but a condensed presentation of the facts from the operating point of view is desirable here. The three principal factors in controlling oxygen are temperature, manganese, and the kind of ore used. The fact that oxygen could be present in cast iron, with its high content of carbon and generally with a considerable content of silicon and manganese, was not admitted until recently, because it was believed that these elements, any or all of them, would unite with the oxygen and carry it off instantly as an oxide.

As a matter of fact this is not necessarily true at all. If the temperature of the bath be kept low, considerable quantities of oxygen—from 1/20 up to 1/10 per cent—can remain in the iron, but as the temperature rises the affinity of the oxygen for the elements mentioned rises very rapidly so that more and more of it is removed as an oxide, and when we reach 2800 deg. or 2900 deg. only traces can remain in the bath.

This is another of those cases of continuously shifting equilibrium so often mentioned, and of the other law apparently almost as general in its application that iron has a much greater affinity for small quantities of all the elements we have discussed than it has for large ones, or perhaps we might say that the reactions which chemistry leads us to expect go on much more slowly as they approach completion and finally reach equilibrium before they are complete.

This difficulty of removing the final traces of oxygen may in this sense be considered as merely the final manifestation of the increasing difficulty of deoxidation as that process becomes more complete, as described in the articles on chemical and thermal principles. We must not ignore, either, the increasing dilution of the oxygen in the bath as it becomes more completely removed.

Next in importance to temperature come the quantities of silicon and manganese present in the bath, carbon being much less important and subject only to minor variations in percentage present so that its effect is approximately constant, whereas the others are subject to variations all the way from fractions of a per cent to several per cent. Manganese is very much more active than silicon in deoxidizing. An iron with 1 per cent Si and 0.5 per cent Mn can probably retain twice as much oxygen as one of 0.5 per cent Si and 1 per cent Mn; in fact, it is probable that only a trace of oxygen can remain with more than 1 per cent Mn, whereas appreciable quantities can be retained with 2 per cent or more Si when the manganese is low.

The third element in the control of oxygen is the character of ore used. Our experience in regard to this is not yet extensive enough to enable us to attach different values to the different ores as regards their oxygen-retaining power in any quantitative way, even the crudest, but there are certain unmistakable qualitative indications which should not be ignored.

I once had charge of a charcoal furnace which was normally operated on a plastic, soft hematite from the Gogebic Range. We decided to try a fine granular limonite from the Mesabi to see whether its greater reducibility would affect the quality of the iron.

Test bars were being taken from every cast and ranged fairly well together for the same grade of iron on the normal ore mixture.

As soon as a burden containing about 25 per cent of the Mesabi reached the hearth the strength of the iron dropped about 10 per cent. The result was so marked and so contrary to the results for which some of our officials hoped for that we repeated the whole experiment, with absolutely identical results.

We had not at that time begun oxygen determinations, so I have no absolute analysis to offer to prove that the oxygen dropped with the more reducible ore, but there is no doubt whatever that it did.

On the other hand, certain irons made wholly or in part from magnetite ore, both with charcoal and coke as fuel, have some of the strength, close-grain, and chilling power of charcoal irons, especially if made on a "raw" slag. It is undoubtedly on account of the oxygen which remains in these irons from the irreducible ore that they possess these characteristics. This has been proven by direct analysis in at least one case.

One plant running under these conditions has always produced iron of a high reputation for strength, and it has recently been extensively advertised as containing vanadium, to which its qualities are ascribed. Vanadium has undoubtedly been found in the iron in very small amounts, but its presence there is purely a coincidence and an unfortunate one, since if there were enough of it the result would undoubtedly be to deoxidize the iron and so destroy the very qualities which the vanadium is claimed to give. The fact is that the quantity of vanadium is too small to take up all the oxygen, while on account of the extreme dilution its action is by no means quantitative, and as a result sufficient oxygen remains in the iron to impart a slight increase in strength as compared with ordinary coke iron, and this oxygen is undoubtedly due to the burden of magnetic ore.

General experience taken in conjunction with these concrete cases enables us to say that other things being equal the most reducible ore produces the iron with the lowest oxygen content. If, therefore, we desire an iron low in oxygen, as is desirable for some purposes, we must run the furnace hot and limy on an ore as high in manganese as the other conditions will permit, and the ore must be of the most reducible kind. On the other hand, if we desire an iron high in oxygen, we must use an ore low in manganese and run on as thin and fusible a slag as will suffice for desulphurization. We should also use at least some fairly irreducible ore, magnetite, mill cinder, or the like.

These are general principles which apply alike to charcoal furnaces and to coke furnaces, but on account of the high temperature of coke iron brought about by the refractory slag on which it is made, the maximum quantity of oxygen which can be retained is smaller and the variations of much less importance than in charcoal iron, in which the minimum amount is as small as in coke iron, but the maximum several times as large. We shall see later that the low temperature at which the charcoal furnace *can* run (though it is often not so operated) on account of its fusible slag, is the reason for the great superiority of its product for some purposes.

We shall see in a subsequent article that we can control oxygen by treatment of the iron after it leaves the furnace better than by any method of operating the furnace. In other words, by operating the furnace to the best advantage and then giving the iron a further treatment external to the furnace we can achieve results out of reach by either method above. By proper treatment of suitable iron we can impart oxygen in greater quantities and under more complete control than can be produced even from a charcoal furnace, while for the limited class of work for which extra soft iron is desired we can produce it by superheating iron of proper com-

position in the electric furnace. The increase in temperature promotes those reactions which remove oxygen and sulphur and give the high temperature necessary for the formation of large flakes of graphite.

The Effect of Slag Temperature on Fracture

In the production of foundry iron arises a feature not covered by the analysis in the ordinary sense. This is the fracture of the iron. It is only about twenty years since all the iron used in foundry work was graded and selected entirely on the fracture and appearance of the pigs, and this custom prevails to some extent even yet. For some foundry purposes it is necessary that the iron be very "soft," which means that when it is melted with a large proportion of scrap iron, broken castings, and the like, it must be able to prevent the mixture from becoming too hard. The general belief of the trade was that iron having a large, coarse crystallization with very shiny crystals was soft iron, while that with fine, close grains was likely to be hard. For this reason foundry irons were very generally desired to be of the open-grained variety, and, in fact, irons not up to the standard in openness of grain were given a lower grade and brought a distinctly lower price in the market, a condition which prevails to-day.

It is therefore important that the iron shall not only have the silicon content desired for a given grade, but that it shall "grain out"; that is, have the openness of fracture which it is the custom of the trade to associate with that grade. We shall later see that sulphur is often responsible for closing up the grain of the iron, and it is undoubtedly on account of the rise of sulphur in the colder irons that a close grain is ordinarily associated with a poor iron. But even though the desulphurization be satisfactory, there are cases in which irons refuse to grade out in a way to correspond with their analysis. This is due, as we have seen and have occasion to emphasize in a later article, to the fact that the iron is made at too low a temperature to remove all its oxygen, and in such cases it is necessary to add lime so as to raise the fusion point of the slag, if the fracture of the product be kept up to match its quality, even though this has a desiliconizing influence on the iron which must be met by additional fuel.

This effect can be obtained in a much greater degree by electrical superheating after the iron leaves the furnace in cases in which the commercial conditions warrant the expense.

Other Occasional Elements in the Charge

In addition to the elements already mentioned there are several others which occur in some raw materials, generally the ore, in greater or less amounts. I have heard of cases in which barium occurred as a base, and when it does, allowance must be made for its fluxing action, which can probably be done tentatively on the basis of its being equivalent, weight for weight, to lime.

Barium sulphate is an occasional ingredient in ores, and is likely to cause trouble by increasing the sulphur from an unexpected quarter. Sulphur from this source simply adds to the total amount to be fluxed.

TITANIUM

There are also in some ores several other metals associated with the iron of which it is necessary to take account. The commonest of these is titanium, which has already been mentioned as an exceedingly common ingredient of many magnetic ores. This element has had a very bad reputation among furnacemen, and many ores have been kept out of the market for years by their titanium content.

The extensive experiments conducted by the McIntyre

Iron Company, and reported to the American Iron and Steel Institute by Mr. Bachman, have already been mentioned. Mr. Bachman states in his paper that the experimental slags made up were calculated on the basis that the TiO_2 was the equivalent in acidity to three-fourths of its weight of silica. He states that there is some reason to believe that the titanium is even less acid than this. Mr. Bachman's calculations were on the basis of considering alumina as an acid, and as this is at variance with the practice which I have recommended of considering alumina as neutral, allowance must be made for this fact in considering his conclusions. Slags containing as much as 22½ per cent of titanic oxide were produced experimentally, and these seemed to have a fluidity almost as high as the corresponding slags without titanium. In practice on the furnace, however, it was not found possible to operate with slags as high as this on account of the tendency of the titanium compounds to build up in the hearth. There was, however, no trouble as far as shown by the several weeks of experiment in operating successfully on a slag containing several per cent of titanic oxide, and there seems to be no longer any reasonable doubt that it is quite possible to operate furnaces successfully on ores containing amounts of titanium which at one time were believed to have been prohibitive. Just what the commercial limits are can be determined in each case only by experience, not simply on test runs but on long runs in regular practice, and will depend not only on technical considerations, but on purely commercial ones, on the relative cost of titaniferous and non-titaniferous ores, their relative fuel requirements, outputs and the like.

It seems proper to note here the pioneer work done by A. J. Rossi, who more than twenty years ago became convinced that titaniferous ores could be worked successfully, and built a small blast furnace some 20 ft. high, on which he carried out a number of tests on these ores, and first demonstrated on an important scale that the ores could be used, and that the slag produced was fluid and could be handled without difficulty if calculated on the basis of titanic oxide as an acid. (See *Transactions A. I. M. E.*, Vol. XXI, page 832.)

As noted earlier a part of the titanium passes into the iron. The quantity obtained in the McIntyre tests ranged around a half of 1 per cent, being roughly constant with quite wide variations in the amount of titanium in the charge, indicating that this is approximately the saturation point of this element under ordinary conditions of temperature in the hearth, etc.

CHROMIUM

This element is unlike titanium in that most of it passes into the iron and but little into the slag. I am advised by Prof. J. W. Richards that the heat of formation of chromic oxide is probably about half that of silicon, so it is very much less than that of titanium. This, of course, facilitates its reduction and passage into the iron. This action is probably greatly assisted by the fact that chromium seems to form a very definite compound with iron and carbon, a double carbide of iron and chromium. This probably means that the iron or iron and carbon together have a more powerful solvent effect on the chromium than they have on titanium, which does not seem to have so definite an action, having a very much smaller effect on the character of the iron. Not much information is available as to the percentage of total chromium in the charge which passes into the iron and into the slag under different conditions. This is probably in part because merchant furnaces cannot use chromiferous ores except in small quantities, and have not therefore developed any information as to the possibilities of slagging it off, etc., the reason being the

very marked effect of chromium on the iron, 1 per cent making it quite hard, and 2 per cent making it entirely unfit for foundry purposes except as a small percentage of the mixture, and rendering the iron fit therefore only for steel works' purposes.

In small percentages nearly all the chromium seems to pass into the iron, but as the percentage rises more and more passes into slag, so that it is said to be impossible to produce in the blast furnace ferrochrome containing over 35 per cent Cr.

NICKEL

Nickel, like chromium, occurs very generally in laterites ores which are the breaking-down products of serpentine rock. Nickel is more reducible than iron, having a very low affinity for oxygen, and therefore all the nickel present passes into the iron, and like phosphorus it can only be controlled by controlling the amount in the charge. Nickel enjoys, however, the unique distinction of being the only element that is beneficial alike in iron and in steel, and there is never any reluctance to having it in the product, except perhaps reluctance to waste so valuable a commodity as nickel on a relatively low-grade product like cast iron, the value of the former being forty to fifty times greater per unit of weight than that of the latter.

COPPER

Copper, like nickel, is more reducible than iron, and all that is present in the charge passes into the iron alloying with it. The effect of this element on a product is generally considered undesirable, and therefore efforts are usually made to keep it out of the charge as much as possible. Some irons of good quality, however, contain as much as 1 per cent on the average, and more on occasion, while tests made by introducing as much as 2 per cent into crucible remelts have shown no effect whatever on the quality of the iron, so that this element has probably been unjustly condemned in the past.

VANADIUM

Vanadium is a metal very difficult to reduce when smelted alone, resembling titanium in this respect, but like the latter considerable fractions of 1 per cent pass into the iron if it is present in the charge. Vanadium is so very valuable that a content of a very few per cent of vanadium makes an ore more valuable for that than for iron, so that as far as known no experiments have ever been made as to the action of a considerable percentage of this element in the blast furnace charge. Little or nothing is known concerning its control.

Other elements, such as tungsten, tellurium and others, are undoubtedly sometimes present in ores of iron in small quantities, but the occasions are so rare and the quantities so small that nothing is known concerning their action.

It may be well to call attention to the fact that in some of the earlier works on metallurgy analyses are given showing considerable percentages of aluminium, calcium, and magnesium in the iron. It is safe to say that these results were due to errors of analysis, since these appear to be three elements which are not dissolved in cast iron to any extent whatever. Presumably the temperature of the furnace hearth and the affinity of the molten metal for them are jointly too small to throw any of them into the bath.

Burdening Without Chemistry

In the early days before chemistry was in universal use in the iron business the burdening of the furnace was done on a practical rather than a chemical basis, and even now it is so done at some isolated plants. The furnaceman learns by the general appearance of his slag the kind which suits his conditions, and with which his

furnace works the best. He learns from both the appearance of the slag and that of the iron to judge of the different grades of iron he produces, and whether, when he varies from it, the furnace is too hot or too cold. He accordingly increases or decreases the burden by an amount depending upon his judgment of what is required. Similarly, if the slag is too lean he adds lime according to judgment, and if it is too limy he removes it on the same basis.

This sounds rather crude at the present day, but much excellent furnace work, both as to regularity and fuel economy, was done on this basis, and it would be very much more correct to say that this was the foundation of furnace burdening and chemical control of the superstructure, than to say the reverse. Even with our advance knowledge of the composition of the coke, limestone, and ore, the factor of judgment can never be omitted or forgotten. Accidental variations arise, the coke is of poorer quality and dissolves more rapidly in the furnace, leaving less for the hearth, or the character of the coal changes in the mine and the coke becomes higher in ash or in sulphur, without notice, or a great mass of many million tons of ore on the Ranges, whose normal analysis is known to one-tenth of 1 per cent, contains an unknown variation from the normal at a certain point, and when in the progress of mining, steam shovels cut into this an ore different from that expected is shipped. These variations are largely eliminated in the mines of the Lake Superior region by careful analysis, sampling and sorting of cars at terminals before making up into cargoes, but in spite of this very considerable variations of the ore from the stated analysis occasionally arise. If nothing else happens an ore of one kind runs down from its own pile onto and over a pile of a totally different kind, and is taken to the furnace for the latter.

In all these cases the furnacemen must use the factor of judgment. The general characteristics of the slag can be quite accurately told by its fracture, especially if a sample of the cinder be poured hot into a small chill mold, since the sudden cooling tends to make the outside of the sample vitreous while the center is stony, and the depth of this vitreous layer in conjunction with other features of its appearance tells the furnaceman whether he is producing the slag that he needs or not. And if one had to choose between such tests of the actual slag, or an advance knowledge of the composition of the raw materials, it would undoubtedly be better and make for more successful operation to take the slag tests and let the analysis go, but the best operation can only be obtained by having both.

It is very desirable not to wait until the furnace has already made a "swing" that will take its product beyond the permitted limits, but to feel this swing coming and by taking quick action prevent it or break its force. This can be done by experienced men by methods which it would be difficult to put into words.

There is another factor in the burdening of the furnace, and in this chemistry has nothing whatever to do. This lies in the fact that the time required to bring through changes of one kind varies considerably from the time for changes of another kind, and the times required will vary within themselves according to the general conditions.

It seems an absurd statement, but a furnace really acts as if it had a reserve of heat, a sort of reservoir, upon which it can draw at need, so that when a bad condition arises for three or four hours, unless it is very serious the furnace is not thrown off its equilibrium, but if the same condition be kept up for half a day or longer the reservoir of heat appears to be exhausted and the furnace then becomes cold.

The same conditions apply to an even greater extent in the case of changes in the limestone burden than they do in changes of ore burden. If a sudden change be made in the character of the burden, for instance, if a more silicious ore be used, or less limestone be charged, it will be found that this change does not come through in the same period that is expected to show any change of ore burden. Generally it takes almost twice as long. On the other hand, if the furnace is running too lean and more limestone be added to the burden the effect of this will not appear for some time after the charge on which the change is made has come through. The furnace acts as though there were a thickness of lime or limy slag on the bosh walls which reaches an equilibrium with the conditions prevailing in the hearth and bosh, that is with the kind of slag that the furnace is making at the time.

I have always assumed that when the equilibrium between the coating on the walls and slag is altered the wall coating tries to make up for the deficiency. If the slag becomes more silicious the wall coating, being limier, gives up lime enough to bring it back to equilibrium. On the other hand, if the slag be made more limy the walls build up their limy coating again before the extra lime is permitted to reach the hearth. It is impossible to say if this is literally true, but certainly the furnace works as if it were, and in recent years I have always been accustomed to making a charge of lime twice as great for the first twelve or twenty-four hours as seemed to be needed. This provides the excess, whether positive or negative, required by the walls, and brings through the charge of lime at the proper time instead of many hours later.

Recent Chemical and Metallurgical Patents

Iron and Steel

Reduction by Liquid or Gaseous Media.—In a patent granted to JOHN W. BECKMAN of Berkeley, Cal., the inventor discloses his process of reducing iron or other metallic ores without the aid of solid carbonaceous reducing agent. The ore or oxide to be reduced is mixed with suitable fluxes and heated to a temperature near the melting point of the mixture. It is then transferred to an electric furnace and heated to about 2000 deg. C., when it becomes liquid. The liquid mass is then transferred to a converter of the Bessemer type, and gas obtained from the cracking of petroleum or the vapors from natural oils is forced into the converter through the liquid ore. The products are pure iron practically free from carbon, and a molten slag. Internal heat is supplied to the mixture during converting to supplant such heat as is dissipated by the gases driven off, this internal heat being provided by admitting with the reducing vapors a regulated amount of air. (1,160,822, Nov. 16, 1915.)

Reducing and Metallizing Iron and Other Ores.—The reduction of metallic oxides or carbonates, producing nodules of metal without fluxing the ore and making a molten slag, is the basis of patents granted to JOHN T. and ALBERT G. JONES of Iron Mountain, Mich. The patents are assigned to the New Metals-Process Co., of Chicago.

Earlier attempts at reduction and metallizing without fluxing and smelting were conducted in long tubular revolving furnaces. The type of furnace patented in the present invention is more on the line of a gas-producer, the hot gases from which are conducted to a tubular dryer through which the ore and fuel are fed to the furnace. The treated ore and unconsumed fuel are discharged at the bottom of the furnace into water, from which the floating fuel is recovered and

dried, while the ore is crushed and treated by jigging for recovery of the metallic globules.

In practice the ore is crushed to a size which permits it to pass a screen of 1-in. mesh. The fuel may be coke, charcoal, wood or coal, and is mixed with the ore in greater proportion than is necessary for reduction of the metallic oxides. The proportion by weight may be two parts fuel to one of ore, and by volume, up to twenty to one. The intention is to afford opportunity for free draft and to keep the particles of ore well separated from each other and accessible to the reducing gases generated by the fuel. The atmosphere in the furnace is maintained in a reducing state, containing preferably carbon monoxide and hydrogen, so that the metal oxides may be converted into metal in nodular form without melting the slag-forming constituents. The furnace is operated preferably by natural draft, but pressure may be employed if desired.

In addition to iron ores, copper oxides and carbonates are amenable to the process. Manganese also may be produced in comparatively large globular masses. (1,174,727-28-32, March 7, 1916.)

Gold and Silver

Slime Agitator.—An improvement in the type of agitator commonly known as the "Parral" is patented by BERNARD MACDONALD of South Pasadena, Cal. The improvement consists in providing the circular tank

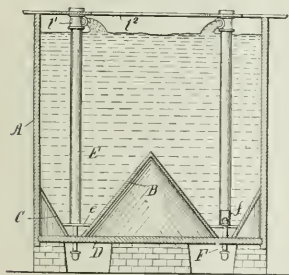


FIG. 1—SLIME AGITATOR

motion of the tank contents, thereby keeping them in suspension and affording opportunity for dissolution of the precious metals in the cyanide solution. (1,163,097, Dec. 7, 1915.)

Copper, Lead and Zinc

Chloridizing Complex Ores.—The method proposed for treatment of mixed sulphide ores of copper, lead and zinc, containing also silver and gold, which was tested experimentally at Helena, Mont., is outlined in a patent recently granted to COURT C. TITUS and WILLIAM J. BARENSCHEER. A diagrammatic flow-sheet is given in Fig. 2. The dry ore is crushed to about eight-mesh, mixed with 5 per cent of dry sodium chloride, and treated with dry chlorine gas in a vessel that is heated externally to maintain a temperature above the melting point of zinc chloride. Sulphur, arsenic and antimony, if present, are volatilized as chlorides and condensed outside the vessel. The heavy metal chlorides, with the associated sodium chloride acting as a flux, collect in a melted condition in the vessel and may be tapped from the gangue. These chlorides are brought into solution in anode liquor from electrolytic cells, containing sodium chloride, free chlorine and oxy-chlorine compounds.

However the solution may be obtained, the object of the process from this point forward is to replace each

of the metal chlorides by sodium chloride, precipitating the metals as such or as compounds, with the result that the final solution is strong brine that may be electrolyzed, with or without previous concentration.

Iron and manganese are first precipitated by the addition of oxidized ores of zinc, such as carbonates and silicates, and sodium hypochlorite which is produced at a later stage of the process. The precipitate of iron and manganese is said to be in a form suitable for filtering by reason of the use of native zinc ores as a precipitate for iron. A further advantage in using native zinc ores for this purpose is that their zinc is easily recovered without the expense of chloridizing. From the clear solution obtained after filtering off iron and manganese, any gold and silver present are precipitated by metallic zinc. Lead, copper, cadmium and bismuth also are precipitated at this stage. In case

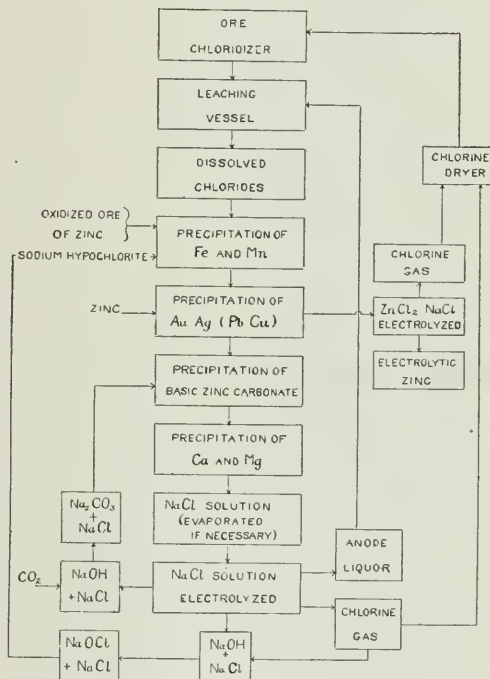


FIG. 2—CHLORIDIZING OF COMPLEX ORES

the original ore contains much lead, it may be advantageous to remove the bulk of that metal by cooling the solution and recovering lead chloride.

After precipitation of the precious and associated base metals the solution consists of the chlorides of sodium and zinc, with small quantities of calcium and magnesium chlorides. This solution is now treated with normal sodium carbonate to precipitate zinc as basic carbonate, care being taken to avoid precipitating the calcium and magnesium. The basic zinc carbonate is collected on filters, after which calcium and magnesium are precipitated by addition of more sodium carbonate, and finally removed by filtration. The remaining sodium chloride is now electrolyzed, the various products being used as follows: chlorine is dried and returned for the treatment of more ore; caustic solution is converted into normal carbonate by treatment with flue gases previously purified, and is used as a pre-

cipitant for the zinc solution; the chlorinated anode liquor is used for leaching. (1,173,467, Feb. 29, 1916.)

Recovering Copper from Tailings.—A proposal to recover copper from the tailing piles of the so-called "porphyry" copper concentrating mills is patented by RICHARD M. ATWATER, JR., of Scarsdale, N. Y. The tailings under consideration contain a large percentage of their copper in the form of carbonate, silicate and oxide which has escaped recovery by concentration. The inventor estimates that the tailings contain from 5 to 15 lb. copper per ton, of which 4 to 10 lb. is in the form just mentioned. This copper is soluble in sulphuric acid, and it is proposed to recover it by spraying the piles with sulphuric acid solution and then allowing the dissolved copper sulphate to come to the surface by capillary action. This would result in concentrating the copper in a comparatively thin surface layer of the pile, from which it could be scraped by hand or mechanically and removed for further treatment. As a rough approximation of the quantity of acid to be used, one might begin with a solution per ton of tailing, containing as many pounds of acid as there is copper per ton in the tailing; or, in other words, pound for pound. The tailing pile would be leveled and laid out in blocks or plots that could be served by a light industrial railway carrying the acid solution. The latter would be sprayed on the surface, after which the plot would be allowed to dry out. This would result in bringing to the surface an efflorescence of copper sulphate in concentrated form which could be collected by scraping. The method is facilitated by a dry or desert climate, and suggests the process adopted at certain cyanide mills in Nevada, where cyanide tailing dumps are sprayed with water and allowed to dry, resulting in bringing to the surface the precious metals that have been dissolved by the cyanide discharged with the tailing. (1,175,331, March 14, 1916.)

Duplex Smelting Process for Zinc Ores.—A method of interrelating the standard retort process of smelting zinc ores with an electrical process, whereby the efficient factors of each method are retained and the inefficient factors dispensed with, is patented by Messrs. WOOLSEY MCA. JOHNSON and EDWIN W. HALE of Hartford, Conn. The electrical step in the method is preceded by certain other conventional steps which will extract the metallic value involving a higher electrical cost of recovery, and which will so condition the material as to bring it into the state best adapted for a high efficiency in the electric furnace step. Thus the retort furnace makes the first two-thirds of its spelter with one-third the total metallurgical effort, and expends two-thirds of the energy in extracting the last third of the spelter. Conditions in the electric furnace are the reverse of this; that is, the electric furnace attains its highest efficiency on mixtures such as exist in the retort furnace during the low efficiency period. Hence the adaptability of a duplex process for the treatment of high-grade ores containing, say, 60 per cent zinc.

The first stage treatment of the inventors' process would consist in retort smelting with a lower percentage of coal and at a lower temperature than customary, and the production of a residue higher in zinc than usual. In the second stage treatment this residue would be mixed with low-grade zinc ore containing considerable iron, and with necessary slagging fluxes. In addition to the fixed carbon contained in the residue, hydrocarbon in the form of coal would be added, and the whole would then be smelted in an electric furnace of the Johnson type after the preheating which is recommended as a part of the process. (1,165,371, Dec. 31, 1915.)

Flotation

Preferential Flotation of Minerals from Mixed Sulphide Ores.—According to a patent granted to HENRY H. GREENWAY of Clare, South Australia, and ALFRED H. P. LOWRY of Prahran, Victoria, Australia, various metallic sulphides can be separated from each other in the flotation process by modifying the circuit liquor with a salt of chromium, such as sodium or potassium bichromate. Another method of treatment is to digest the sulphides with a chromium salt solution before flotation. The following examples are given: From an ore of molybdenum containing 15 per cent MoS_2 and 25 per cent FeS_2 , the flotation product contained 93 per cent MoS_2 and 4.9 per cent FeS_2 . In making this test the ore was crushed to 100-mesh and agitated with four times its weight of water at 120 deg. Fahr., containing in solution 0.25 per cent sodium bichromate and eucalyptus oil in proportion of 1 lb. per ton of ore treated. A copper ore containing 6.5 per cent copper and 35 per cent iron yielded a float containing 19 per cent copper and 30.2 per cent iron, with a tailing of 0.7 per cent copper and 36.2 per cent iron. A lead-zinc slime containing 18.6 per cent lead and 32.2 per cent zinc was digested for 30 min. in warm water containing 1 per cent sodium bichromate. On agitation with eucalyptus oil, 1 lb. per ton, this slime yielded a flotation concentrate containing 47.2 per cent zinc and 6.3 per cent lead, and a residue of 31.6 per cent lead and 16.3 per cent zinc. In most cases the best results are obtained at a temperature of from 120 to 150 deg. Fahr. (1,102,738, July 7, 1914.)

An improvement on the method of Greenway and Lowry is patented by HENRY LAVERS of Surrey Hills, Victoria, Australia, who states that the results obtained by the use of sodium or potassium bichromate are greatly improved if the water is made slightly alkaline, as by the use of sodium carbonate equivalent to 1 per cent by weight on the ore. The inventor finds that by using the ordinary agitation froth process in alkaline water he gets practically all the metallic sulphides, which may then be separated from each other by re-treatment in solution containing the chromium salt. A temperature of 130 deg. Fahr. is indicated. The following example is given: Slime containing 11.6 per cent lead and 13.4 per cent zinc was treated by the agitation froth process in alkaline water, yielding a concentrate containing 22.2 per cent lead and 27.4 per cent zinc. This concentrate was then subjected to preferential flotation in alkaline solution with the addition of sodium bichromate to the extent of 6 lb. per ton, kerosene equal to $\frac{3}{4}$ lb. per ton of concentrate and eucalyptus oil equal to about $\frac{1}{8}$ lb. The flotation product contained 48.6 per cent zinc and 7.5 per cent lead, while the residue contained 8.9 per cent zinc and 55.9 per cent lead. (1,142,821, June 15, 1915.)

Preferential Flotation of Galena and Blende.—A process patented by THOMAS M. OWEN of Sydney, New South Wales, Australia, is based on the discovery that the addition of minute quantities of potassium permanganate to slime which contains a mixture of lead and zinc sulphides will permit a separate flotation of the two minerals. The quantity of permanganate used is less than the quantity required to oxidize the reducing agents present in the slime or the water. The chemical is not added to the water used for treatment, but to the pulp of slime and water. Normal temperatures may prevail, or the process may be conducted at a temperature of 120 deg. Fahr. when the slimes are of a highly reducing character and likely to decompose the permanganate rapidly. The process is primarily useful on weathered slime, even a short weathering of a few hours being found advantageous. In some cases

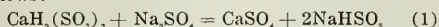
a deadening agent, such as sodium hydrate, may be used to intensify the tendency of the minerals to float separately.

In carrying out the process the slime is mixed with non-acid water, agitated, treated with potassium permanganate followed by the frothing agent. The mixture is then treated by froth flotation, with the result that the lead floats. The residue is then resubmitted to froth flotation after acid (15 lb. H_2SO_4 per ton of slime) has been added, with the result that the zinc then floats. In practice the two flotation liquors, for lead and zinc, are kept in separate circuits, fresh water being added to the first circuit in which no acid is used. By way of example of the results obtainable, the following is cited: A weathered slime from Broken Hill contained 16 per cent lead, $13\frac{1}{2}$ per cent zinc and 17 oz. silver per ton. In this treatment, $2\frac{1}{2}$ lb. potassium permanganate and 3 oz. eucalyptus oil were used per ton of slime. A lead concentrate was first obtained, carrying 60.5 per cent lead, 54 oz. silver and 11.8 per cent zinc. After adding acid and retreating, a zinc concentrate was obtained containing 6.2 per cent lead, 11.2 oz. silver and 43.4 per cent zinc. The final residue contained 2 per cent lead, 3 oz. silver and 1.6 per cent zinc. (1,157,176, Oct. 19, 1915.)

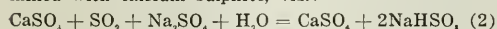
Synopsis of Recent Chemical and Metallurgical Literature

Chemical Engineering

Utilization of Nitre-Cake.—An interesting description of a method for the utilization of nitre-cake by Dr. J. GROSSMANN appeared in the *Journal of the Society of Chemical Industry*, Feb. 15, 1916. It is well known that calcium hydrogen sulphite, known in commerce as bisulphite of lime, is decomposed by sodium sulphate as follows:



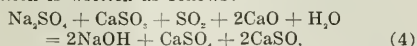
A similar reaction takes place if sulphur dioxide is passed through a solution of sodium sulphate which is mixed with calcium sulphite, viz.:



If now the insoluble calcium sulphate is separated from the liquid part, a solution of sodium hydrogen sulphite is obtained, from which by adding lime, caustic soda is obtained in solution, and a precipitate of calcium sulphite:



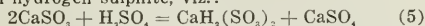
But for every equivalent of calcium sulphite which was originally used we obtain back two equivalents, so that one equivalent is wasted. This appears clearly if the equation is written as follows:



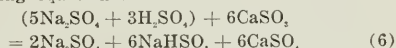
This waste is one of the reasons why this reaction, which was first proposed nearly forty years ago, has not been used for the technical manufacture of caustic soda. For not only must one equivalent of calcium sulphite be removed from the cycle of operations, but the addition of one equivalent of sulphurous acid which this involves complicates the working, and adds to the cost of the plant and process.

If a solution of nitre-cake is used instead of a solution of sodium sulphate, the reactions which take place are more favorable for practical results. Nitre-cake is theoretically a mixture of sodium sulphate and sodium hydrogen sulphate, which for practical purposes is generally looked upon as a mixture of sodium sulphate and free sulphuric acid. Thus, for example, a nitre-cake showing by test about 30 per cent of free sulphuric acid

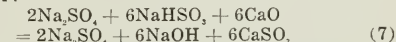
could be expressed by the formula, $5\text{Na}_2\text{SO}_4 + 3\text{H}_2\text{SO}_4$, which corresponds to 70.7 per cent Na_2SO_4 and 29.3 per cent H_2SO_4 . It is well known that calcium sulphite can be decomposed by sulphuric acid so as to yield calcium hydrogen sulphite, viz.:



Thus the free sulphuric acid produces the same effect as the addition of sulphur dioxide in equations (2) and (4). A solution of the nitre-cake mixed with calcium sulphite would therefore decompose according to the following equations:



and further:



It will be seen that we finish up in equation 7 with the same quantity of calcium sulphite with which we commenced in equation 6, so that theoretically the original amount of calcium sulphite used would be sufficient for any number of operations. The solution after separation from the calcium sulphite contains mainly caustic soda and sodium sulphate, the latter free from iron and other impurities which have been removed by the lime in the causticizing process. On boiling down, sodium sulphate is fished out, and the final liquor is either used as such or further concentrated and made into solid caustic soda. Incidentally, I may mention that the calcium sulphate produced may possibly be made into pearl hardening, and thus yield a third commercial product.

In practical work it is, of course, not possible to obtain the results as shown in the above equations; a certain amount of calcium sulphite will have to be replaced, requiring the use of lime and pyrites, and the yield in caustic soda, so far as can be judged from laboratory experiments and other considerations, will probably only be two-thirds of the theoretical quantity, so that from 100 tons of nitre-cake about 36 tons of pure sodium sulphate and 15 tons of caustic soda as NaOH would be obtained. The cost of lime and of replacing calcium sulphite would amount to somewhere about £50, that of labor to about £40. About 400 tons of water would also have to be evaporated which, with steam for power, would require about 80 tons of coal, though in multiple effect less than half that amount should be sufficient. Taking it, however, at its worst, with coal at £1 per ton, the charge for fuel would amount to £80, bringing the total expenditure to £170. As the plant would be extremely simple and, without multiple apparatus, cheap, a further £10 per week for depreciation and other charges should be sufficient, so that a total expenditure of £180 per week, at present prices and with crude plant, should be sufficient to work up 100 tons of nitre-cake.

Against this must be considered the revenue to be derived from the sale of caustic soda and sodium sulphate. The sodium sulphate obtained by this process would be purer than saltcake, and should therefore, under equal conditions, realize at least the same price. The price of saltcake at present is £2 2s. 6d. per ton, at which price it is practically unsalable. If we consider that soda ash is at present sold at £3 2s. 6d. per ton, its equivalent in sodium sulphate is less than £2 6s., so that there is not much inducement for glass-makers to buy it at present prices. I therefore take the price of sulphate of soda in my calculations at only 25s. per ton naked at the works, at which price one could reasonably expect to be able to compete with soda ash where it can replace the latter, and the revenue from this source would therefore be on 36 tons £45 per week. The price of 70 per cent caustic is at present an un-

known figure, but ranges from £16 or £17 per ton up to £20 per ton and more. Taking pure caustic, on which these calculations are based, at £14 per ton naked at the works, the revenue from this would amount to £210 per week, and adding the two products together, we have a revenue of £255 per week against an expenditure of £180, leaving a margin of £75, or 15s. per ton of nitre-cake.

Any new process which is to be taken up in these exceptional times, however, should not only show a reasonable profit under present circumstances, but should also prove to be practicable under more normal conditions, though at present it appears most unlikely that for many years, at any rate, we shall have such low prices as we have had in the past. Now it will be seen that the chief expenditure in this process is coal, and that once the feasibility of the process has been established, it would pay to put up more expensive plant in the shape of multiple effect evaporators. That alone would effect a reduction of £50 per week in the expenses. At the same time, the expense for lime and for replacing calcium sulphite and other chemicals would be reduced by at least one-third, causing a saving of about £20, so that with the reductions in these two items, not reckoning any reduction in the cost of labor, we should have an expenditure of £110 per week. Against this, we should have a revenue from sodium sulphate, which should be the same as before, £45 per week, and 15 tons of caustic soda at, say, £9 per ton, *i.e.*, altogether £180, leaving a margin of £70. It thus appears probable that the expenses would be less in proportion as the prices of the materials obtained became reduced, and that the process, which is provisionally protected, would, even in normal times, yield sufficient profit to render its use practicable.

Nothing was allowed for the cost of the nitre-cake. Most works were only too glad to get rid of it, and some might even pay for having it removed. On account of freight expense, it would be advisable to install the works near to those where the nitre-cake was produced. It was necessary to work with somewhat more dilute solutions than in the causticizing of sodium carbonate. It was not to be expected that during war time anyone would put up a costly plant. It is likely that at present ordinary methods of evaporation would have to be adopted, though even then the cost of evaporation would not be prohibitive. With multiple effect apparatus the cost of evaporation would not differ much from that incurred in the manufacture of caustic soda from sodium carbonate or Leblanc soda lyes.

Saline Method of Water Flow Measurement.—In the *General Electric Review* for February, 1916, W. D. PEASLEE gives a description of a method of water flow measurement by the use of salt which has been in use by several large operating companies for measuring the water taken by their power turbines. The method depends upon the introduction at a constant rate of a dosing solution made of salt, with subsequent mixing and then the sampling at a point further on in the stream. The samples are analyzed and from the amount of salt per unit volume the amount of water passing (rate of flow) can be calculated very easily, since the amount of salt added per unit time is known. The relation does not depend on the cross-sectional area of the stream or on any velocity determinations, and results depend on the following conditions:

- (1) Amount of salt per unit volume in samples taken.
- (2) Constant dosing rate.
- (3) Perfect mixtures.

Two methods are given by the author for analysis of the samples, the volumetric titration method using silver nitrate, and the conductivity method, using elec-

trolytic determinations of the resistance. The titration method is stated to give an accuracy of 0.1 per cent with a little experience but the conductivity apparatus as developed by the author is simpler and more easily carried about. It consists of a U-tube with platinum electrodes, a conductivity meter and a continuous current hand-driven dynamo. A curve of correction factors for temperatures is necessary as the conductivity varies with the temperature. The instrument is calibrated with standard salt solutions and can be packed in a portable case.

To secure a constant flow of dosing solution a standard orifice is used, and it has been found that any pump, rotary or reciprocating, will effect a perfect mixture as will a water wheel or turbine.

Ore-Dressing

Concentrating Molybdenite.—The dressing of molybdenite ores in New South Wales, Australia, is not up to the standard attained in this country, if one may judge from a description of operations given in the *Australian Mining Standard* for March 2, by E. C. ANDREWS.

The process, in the main, consists in crushing and dry screening. Experiments in water and oil flotation are being conducted, but no large tonnage has as yet been treated by these methods. Where the ore consists of molybdenite flakes of moderate size in quartz, the rock is crushed and the larger flakes of mineral sorted by hand, while the smaller grains are saved by hand screening. At larger deposits, where the ore contains bismuth mineral with the molybdenite in a clean gangue of quartz or silicious granite, more elaborate screening methods are employed. For instance, at one mill of 5 tons capacity the ore is crushed to 1-in. size by jaw breaker, further reduced in rolls and then screened to recover the larger flakes of molybdenite. The screen oversize is again rolled and screened, the holes in the shaking screens being 1/12 in. in diameter. The undersize passes onto a Wilfley table to recover the bismuth; the undersize is further crushed to 1.20-in. size and again screened by hand, obtaining a high-grade molybdenite in the oversize.

At one mill oil flotation is in operation. The oiled pulp is delivered into horizontal shaking troughs discharging into boxes filled with water. The molybdenite floats and is discharged into launders leading to a 180-mesh screen, which separates the valuable product. The apparatus is arranged for fourfold treatment of the ore by successive treatment of the tailings in the manner just described.

The History of a Prominent Metallurgical and Industrial Engineering Firm

Announcement has been made of the incorporation of The Dorr Company, successor to The Dorr Cyanide Machinery Company, as a result of the expansion of its business and professional service, due to the increasing use of Dorr machinery in so many varied processes and industries. The Dorr Company has taken over the patents and commercial business of its predecessor, and will act in a consulting capacity in connection with the design, construction and operation of hydrometallurgical, wet chemical and allied industrial plants and the conduct of technical investigations.

John V. N. Dorr, the president of the company, was born in the Oranges, N. J., and educated as a chemist. After several years in industrial chemical research (including two years in the laboratory of Thomas A. Edison), he went West and engaged in metallurgical work. He obtained his cyanide experience largely in the Black Hills, South Dakota, where after a period as

chemist he leased and operated a custom cyanide plant under the firm name of Lundberg & Dorr, and later erected and operated the first plant (the Lundberg, Dorr & Wilson Mill) to use continuously and successfully the Moore filter. In this mill the Dorr classifier was developed. It was designed and first used for making a separation of clean sand for leaching in tanks from slime for treatment by decantation or filtration. Other operators who saw it wished to use it, and its manufacture was commenced in 1906.

The development of filtration brought with it the "all-sliming" process and the classifier was then used in closed circuit with tube mills for making a product from 100 to 200 mesh. The introduction of the flotation process created a demand for milling a 40 to 80-mesh product in copper, zinc and lead mills, and the classifier has been used for this purpose with ball mills by such companies as Anaconda and Inspiration. The recognition of the need of desliming before hydraulic classification and tabling involved its use for that purpose. It was also apparent that it could be used for dewatering tailings, and it has been so used. The standard machine was originally designed to handle 100 tons, but the duty demanded has increased, and machines with a total feed of 1200 tons a day are now in use separating at 48 mesh, while one-fourth-size machines to handle a few tons a day are also made.

In 1906 Mr. Dorr invented his thickener when remodeling the mill of the Mogul Mining Company, also in the Black Hills. In 1907 he moved to Denver and arranged for the manufacture of both machines, although giving most of his time to consulting work and the operation of mills in South Dakota. As the classifier and thickener became known through wider use, the demand for them increased rapidly, especially in Mexico and the United States. No advertising, however, was done until over 200 machines were in use.

In 1910, on account of the growth of the business, The Dorr Cyanide Machinery Company was incorporated.

In 1911 the London office of the company was established, with Mr. William Russell in charge. During the same year an engineer, Mr. H. N. Spicer was sent around the world in the interests of the company. The introduction of Dorr machinery in India, Australia and other places followed. A by-product of this trip was Mr. Spicer's series of articles on the evolution of methods for handling slimes in India, New Zealand, Australia, South Africa and Rhodesia, published in METALLURGICAL AND CHEMICAL ENGINEERING, Vol XI, pages 181, 239, 315, 408, 451, 481, which our readers will surely remember with pleasure.

The Dorr thickener was first used in cyaniding to replace large cones and intermittent settling where grinding in solution was done. Its value was appreciated immediately and it has been installed very extensively throughout the world.

The advantages of a change in solution for assisting dissolution, especially on silver ores, and the losses that were found most common in filtration called for the extension of the thickener to counter-current decantation, either with a single displacement for increased dissolution or with four or five to supplement or entirely replace filters. The development of the Dorr tray thickener in 1913 reduced the objection of large ground space required for counter-current decantation, and on small plants has still further simplified matters by allowing the substitution of two slightly deeper tray tanks for four normal ones.

To the concentrating man the thickener did not appeal so readily because it frequently was considered that the small cone with its feed to the individual tables

was better suited to concentrating conditions. However, the development of slime treatment methods, especially flotation, caused its introduction, and within the last three years practically all of the well-known copper, zinc, and lead districts have adopted it. Used originally for producing a flotation feed of the proper density, it has been further utilized for thickening flotation concentrates before filtration and the recovery of water from flotation and other tailings.

The use of Dorr thickeners in industrial work has increased, and they are now used in rubber recovery, caustic soda production, and in many other places where the separation of finely divided material is required.

The original thickener was operated on classified slime in a tank 35 ft. in diameter. The size of tanks has been rapidly increased, and there is now in use a thickener in a concrete tank 130 ft. in diameter, while one for a 200-ft. tank is under construction. It has been developed to handle as coarse a product as 40 mesh.

The Dorr agitator introduced in 1912 is operating in nearly all of the well-known cyanide mills erected since that time in the United States and Canada, and many have been shipped to South America and the Eastern Hemisphere.

The classifier, thickener and agitator all operate continuously with exceedingly small costs for power, maintenance and attention.

About this time the introduction of the continuous counter-current decantation system with the use of Dorr thickeners in cyaniding attracted the attention of metallurgists, the first installation being made at the mill of the Vulture Mines Company in Arizona by Mr. Dorr. The further increase in the business and the opportunities for the application of Dorr machinery in various industries other than metallurgy led to the opening of a New York office about the end of 1913, and the expansion of the company's quarters in Denver.

Mr. Dorr has remained continuously connected during this development with the operation of one or more mills, and the company has been in close touch with a large number of plants, so that the development and improvement of its machinery has been handled from the viewpoint of the mill operator.

The company, during the last few years, has designed a number of mills, and among them the Vipond cyanide plant at Porcupine, Ont., the Rochester Mines Company at Rochester, Nev., and a cyanide plant for the South American Development Company in Ecuador. The description of the Rochester mill by our Western editor, published elsewhere in this issue, will be found particularly interesting.

During the last year the company financed, designed, and erected a mill for the Elko Prince Mining Company at Midas, Nev., and is now operating the property for that company.

The consulting department of The Dorr Company, through keeping in close touch with the latest developments in metallurgy, is equipped to render progressive service in the design and erection of plants and the investigation of processes, and to supervise the operation of a limited number of properties. Service of this kind is valuable not only to those property owners who are more interested in results obtained than in the type of equipment required to accomplish them, but also to those who do not find it possible to retain the entire services of men capable of efficiently designing or operating their plants.

The general offices and headquarters for metallurgical and industrial work will be at Denver and at New York City, while the London office and the Australian agency will be maintained as before.

Mr. A. L. Blomfield, for the past eight years superintendent of the Golden Cycle Mill at Colorado Springs, has recently become affiliated with The Dorr Company, but retains charge of the Golden Cycle Mill as general superintendent. The mechanical engineering staff of The Dorr Company has at its head Mr. W. A. Neill, who, for the previous eleven years, was chief engineer of the mining department of the Allis-Chalmers Manufacturing Company. Mr. H. S. Coe has charge of the laboratory and research department for the company. Mr. P. M. McHugh is the metallurgical sales manager for the company, while Mr. H. N. Spicer will continue in charge of industrial work at New York. Mr. Wm. Russell, a metallurgist formerly with the McArthur-Forrest Company, who has been in charge of the London office since it was started, will continue there.

Fluid Meter for Steam, Water and Gases

The measurement of steam flow is one of the most difficult engineering problems that has ever been attempted. It resolves itself into two distinct parts: first, to obtain a pressure difference that varies in a known and definite manner with the rate of flow, and, second, to accurately measure, record and integrate the rate of flow by means of this pressure difference. In a very extended investigation carried out by the Bailey Meter Co. of Boston, Mass., a great many experiments were made with Pitot tubes and multiple-hole nozzles, and many variations in their design were tried. They

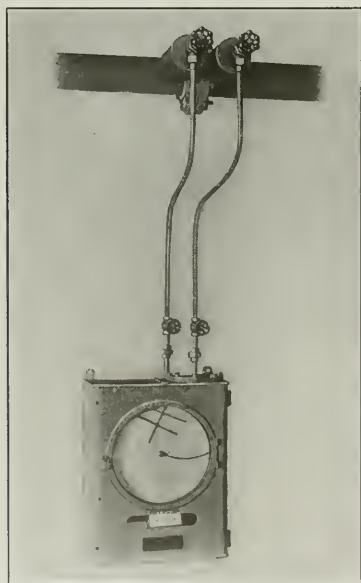


FIG. 1—METER PLACED FOR STEAM MEASUREMENT

proved to be unreliable in all cases except in long runs of straight pipe, and even there the latter did not maintain their accuracy for any reasonable length of time.

After very extended investigation a special type of orifice was devised, which furnishes a good means of securing the required pressure difference. It has the advantages of low cost, being easily installed and of giving constant accuracy over very long time. The size of the orifice is properly proportioned to the size of pipe and the meter capacity desired, so that the stand-

ard recorder can be used from the lowest to the highest velocities without changing the piping in any way.

The pressure loss caused by the orifice is never more than about one pound, which is less than that caused by an ordinary elbow, globe valve, or non-return valve with present-day velocities. A great deal of testing and calibration work has been necessary to determine the coefficients of flow for orifices of different diameter in the various sizes of pipe. This experimental work has been extended over several years in order to prove that there was no change in accuracy.

This meter works upon the principle of accurately

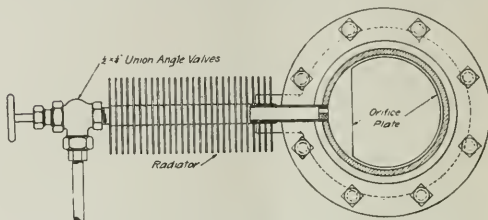


FIG. 2—SEGMENTAL ORIFICE AND RADIATOR IN HORIZONTAL PIPE

measuring the pressure difference across an orifice placed between a pair of flanges in a pipe line, as shown in Fig. 1.

The special orifice plate which is used is made of 1/32-in. Monel metal and is corrugated near its outer edge so that it forms its own gasket without any other packing or thickening up of the joint in any way. The size of the orifice is proportioned to the size of the pipe, the quantity and density of steam or other fluid flowing through it, so that about 1/2-lb. pressure drop is secured at average rates of flow. With this small pressure drop no cutting action occurs, and the orifice plate is entirely free from corrosion.

A sectional view of an orifice installed in a horizontal pipe is shown in Fig. 2. This particular orifice is of segment shape, which is used in high-velocity work, so as to secure the correct pressure difference without undue obstruction.

Circular orifices of relatively smaller diameter are used for lower capacities. In such cases a small drain hole is located in the orifice plate at the bottom of a horizontal steam pipe to prevent any accumulation of water.

When metering steam it is necessary to have the bell casing and connecting pipes completely filled with water up to an equal and constant level. Each time the bell rises or falls some water is drawn down in one pipe and an equal volume forced up in the other. It is practically impossible to have large enough reservoirs on a level with the steam pipe connections to answer this purpose, but the radiators shown in Fig. 2, consisting of a horizontal piece of 1/2-in. copper pipe with a number of washers or fins, serve to keep the water level and at substantially equal temperatures in the two connecting pipes.

Fig. 3 shows in detail the construction and operation of the Bailey fluid meter. The higher and lower pressures from the up-stream and down-stream sides of the orifice are connected to valves *H* and *L* respectively. Valve *B* is a by-pass which serves to equalize the two pressures when desired. From valve *H*, the higher pressure is conducted through pipe 90 and tube 117 to the space within the mercury-sealed bell. From valve *L* the lower pressure is conducted through tube 118 to the interior of the casing, which is subjected to full

pipe-line pressure of the steam or other fluid being metered.

The liquid shown in the reservoir is mercury and the entire casing and piping are completely filled with water at all times when used as a steam or water meter. The bell is entirely closed, except at its lower end, which is sealed by the mercury contained in the reservoir, so that the pressure H , applied through tube 117 to the space within the bell, which is in excess of the pressure L , applied through tube 118 to the space without the bell, tends to push the bell upward in proportion to the pressure difference. This pressure difference acts as if applied to a piston having the area of the inside of the bell at the surface of the mercury. In the normal or zero position of the bell it is almost completely submerged in the mercury, and is held in the mercury by the bell-weight, supported by a yoke fastened to the top of the bell. An increase in pressure difference forces the bell upward, and as it rises out from the mercury the change in the buoyant action of the mercury on the walls of the bell exactly balances the force due to the pressure difference. By suitably varying the area of the bell and also the thickness of its walls the resulting motion can be varied in any desired manner.

The shape of the bell in this meter is designed in accordance with the actual flow curve corresponding to the

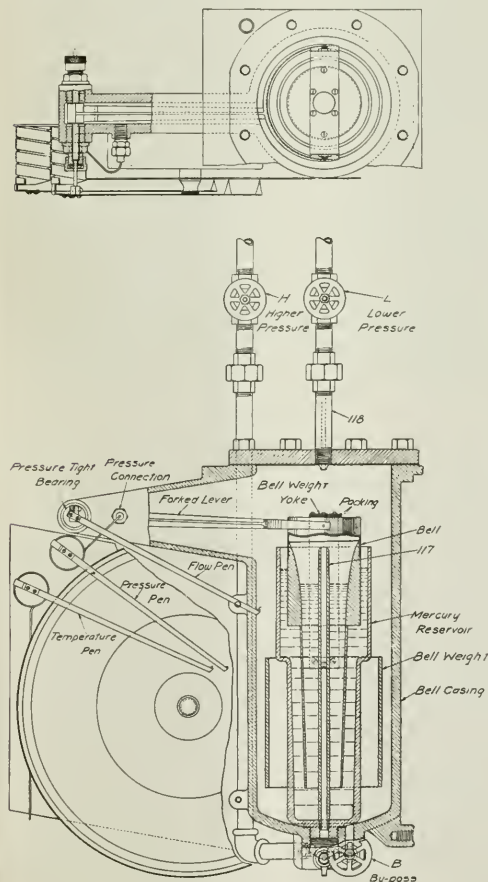


FIG. 3—CROSS-SECTION OF METER

pressure difference and rate of flow through the orifice, so that a direct reading chart with uniform graduations is used and the proper integrator motion is secured without adding one iota to the friction or complexity of the mechanism. The flow curve is similar to a parabola, and there is relatively much less head or pressure difference at low rates of flow than at the higher rates. For instance, the head available to operate the meter at 10 per cent flow is about 1 per cent of the head at

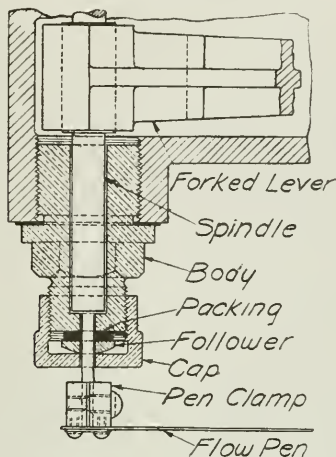


FIG. 4—DETAIL OF PRESSURE TIGHT BEARING

100 per cent, or maximum capacity of the meter. The same condition holds true for Venturi tubes, Pitot tubes, multiple-hole nozzles, etc., as means for producing a pressure difference, but the large area of the bell which is effective at the low rates of flow, together with the absence of friction, gives a great degree of accuracy over a wide range of flow.

The spindle, which is given a rotative motion by the movement of the bell, has ends of small diameter which pass through a pressure-tight bearing, shown in detail in Fig. 4. This pressure tight bearing should not be confused with a stuffing box or cup leather packing, for it obviates the objectionable features of both of these.

All danger of spilling mercury in shipping and installing is obviated by having the mercury hermetically sealed in the reservoir by means of a lid and gaskets held in place by a wing nut.

Another valuable feature of this meter is the automatic shut-off which prevents blowing out of the mercury or other damage when either of the pressures is excessive, due to an abnormally high rate of flow, improper opening of valve, or even the breaking of one of the connecting pipes.

Two recording thermometers can be used equally well in connection with an orifice feed water meter, such as Type C2, where one thermometer records the temperature of water entering the economizer and the other records the temperature leaving the economizer. A chart graduated from 100 deg. Fahr. to 350 deg. Fahr. is supplied for this purpose. This meter can be provided either with or without an integrator.

Many weighed water calibrations have been made on these meters measuring both steam and water at intervals over considerable periods of time. The great majority of such calibrations have shown an agreement between the weight and meter readings within 1 per cent. In but very few cases have the differences exceeded 2 per cent.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Aqueous Bath Cathodes

(Continued)

633,315, Sept. 19, 1899, Charles W. Heergeist of Philadelphia, Pa., assignor of one-half to Charlton H. Royal of same place.

Relates to making signs and the like by electrodeposition, the letters or characters being in intaglio. Upon a suitable smooth metal plate are secured letters or characters in reverse order, by wax or other adhesive. The surfaces of the letters and of the metal plate are prepared so that the deposit may be readily stripped therefrom. After the deposit is completed, it is stripped from the plate, the letters or characters are then removed from the deposit, and the face of the deposit dressed to remove sharp edges, etc.

634,523, Oct. 10, 1899, George Epp of Vienna, Austria-Hungary.

Relates to the production of patterned metal foils which are mounted upon paper, linen, leather, etc. A German silver matrice, suitably engraved, has its surface treated by immersion in a solution of sulfantimonate of sodium for a few seconds, which produces a surface from which the deposit may be readily stripped. The treated matrice is now connected as cathode in a nickel plating solution, which shows a slightly acidulated reaction, and a current at from two to three volts passed through for two or three minutes. The nickel deposit is then reinforced by a copper deposit, and the mounting of paper, linen, etc., then applied. It is then stripped from the matrice.

655,344, Aug. 7, 1900, James Hargreaves of Widnes, England.

Relates to cathodes for electrolytic cells, and is a division of an earlier application. The cathode consists of woven wire cloth which has been rolled so as to flatten out its prominent points such as the cross wires. The cathode thus flattened is secured to the diaphragm as in the well known Hargreaves-Bird cell. It is said that the new cathode effects a reduction in the resistance while increasing the electric osmose and decreasing the Grahamic osmose, resulting in a reduction in the undecomposed electrolyte passing into the cathode space of the cell.

660,416, Oct. 23, 1900, Sherard Osborn Cowper-Coles of London, England, assignor of one-half to The Reflector Syndicate, Limited of same place.

Relates to the manufacture of reflectors, and consists in using a highly polished truly-shaped cathode of speculum metal. The speculum metal may be composed of fifteen parts tin, thirty-two parts copper, and one part arsenic; or it may consist of one part tin and two parts copper. The molten alloy is carefully poured into an iron mold, and after cooling, is removed and dressed as desired, and polished. Its surface is now coated with a thin film of beeswax dissolved in a suitable solvent, to facilitate the easy removal of the deposit. The body of the reflector is then deposited and is reinforced by a deposit of copper. It is then removed from the cathode, and the reflecting surface is coated with a deposit of platinum, palladium, or chromium. The platinum bath consists of freshly precipitated double chlorid of platinum and ammonium, dissolved in a boiling concentrated neutral solution of citrate of sodium, and should con-

tain about 1½ ounces of platinum per gallon. The current should have a density of about 3 amp. per square foot of cathode surface, and the difference of potential between the terminals of the depositing cell should be about three-quarters of a volt.

683,263, Sept. 24, 1901, Elmer G. Elliott and Valentine Kishner of Perth Amboy, N. J.

Relates to the making of starter sheets for use in the electrorefining of copper. A base cathode of either sheet lead or sheet copper is provided with a "scratch-groove" around its edge or on its surface near the edge, and copper deposited over the entire base cathode. After a thickness of about 1/32 of an inch has been deposited, the deposit is raised at one end and torn off, the scratch-groove having the property of preventing a continuously uniform deposit, and permitting the easy tearing of the metal along the scratch, and separating it from the base. The sheet thus separated may be used as a cathode of pure metal for the deposition of copper in electrorefining.

684,291, Oct. 8, 1901, William A. McCoy of Perth Amboy, N. J.

Relates to the making of starter sheets for use in the electrorefining of copper. A base cathode of sheet copper is provided near its bottom and side edges with a row of depressions or perforations, close together, and filled with insulating material. The deposit of copper forms upon the plate and upon the narrow portions of metal between the depressions or perforations, the deposit upon the narrow portions being readily torn thereby permitting the easy removal of the deposited sheet, which is used as a cathode for the deposition of metal in the refining vats.

Obituary

Harry Clary Jones, professor of physical chemistry at Johns Hopkins University, died suddenly on April 9 at his home in Baltimore, Md. He was born in New London, Md., on Nov. 11, 1865, and graduated from Johns Hopkins in 1889. Later he studied at the Universities of Leipzig, Amsterdam and Stockholm. In 1895 he became an instructor in physical chemistry at Johns Hopkins, in 1904 a full professor. He was one of the staunchest defenders of the electrolytic dissociation theory and a prolific and brilliant author and lecturer.

Personal

Col. D. C. Jackling is cruising in South American waters in his yacht the *Cypress*. He and his guests are understood to have in view the expediency of taking over options upon large Bolivian tin properties.

Mr. B. T. Colley, smelter superintendent of the Braden Copper Co., has returned to Chile from the States.

Dr. L. H. Baekeland gave a talk before the Patria Club in the Seventh Regiment Armory on April 7 on our needs for chemical preparedness.

Mr. C. A. Lunn, director of the flotation oils department of the General Naval Stores Co., New York, is making a trip through Colorado, Utah, Idaho, Montana and Nevada in the interest of flotation oils. Mr. Lunn has been engaged for several years in developing oils for flotation work.

Mr. George E. Dyck has recently been appointed industrial chemist, Chicago Bureau of Waste, and will have charge of the municipal garbage reduction works. He was graduated in chemical engineering from Kiel University, Germany, in 1890 and for a year following was a lieutenant in the German navy. After coming to this country in 1891 he was employed by Morris

& Company, St. Joseph, Mo., leaving them in 1897 to become chief chemist of the National Provisioner Laboratory in New York. From 1899 until 1902 he superintended the manufacture of fertilizer and sulphuric acid for the Virginia & Carolina Chemical Company of Memphis, Tenn. For two years thereafter he was superintendent of the Chicago Reduction Company and from 1904 to 1907 was with Sulzberger & Sons Company as department manager of fats, oils and fertilizer. Since that time he has been the head of the Agricultural Laboratory in Chicago except during the last half year, when he was an instructor in the Siebel Institute of Technology.

Mr. R. J. Wysox, formerly chief chemist, has been appointed superintendent of the blast-furnace department of the Bethlehem Steel Co., South Bethlehem, Pa.

Dr. Walter F. Rittman has severed his connection with the Bureau of Mines and will devote his time to the Rittman Process Co., of which he is the vice-president. Mr. E. W. Dean has succeeded Dr. Rittman at the Bureau of Mines in Pittsburgh.

Mr. Thomas W. Pritchard has severed his connections with Messrs. E. B. Badger & Sons Co. in order to become manager of sales for the Niagara Alkali Co. and the Electro Bleaching Gas Co., with headquarters at 18 East 41st Street, New York City.

Mr. G. C. Riddell has resigned as superintendent of the American Smelting & Refining Co.'s lead plant at Helena, Mont., and will become superintendent of the Burma Corporation smelter, Numa, Burma, India.

Mr. Charles F. Rand sailed for Cuba on March 26 with a party of other gentlemen, mostly officials and engineers of the Bethlehem Steel Co. The Mayari and other properties now owned by the Bethlehem Steel Co. will be visited.

Mr. William G. Schneider, manager of the smelting plant of the Magnolia Metal Co. at Matawan, N. J., has resigned due to poor health and will devote the next month to recuperation.

Mr. W. J. Richards, president of the Reading Coal & Iron Company, announces the appointment of George S. Clemens of Pottsville as consulting engineer of the company, a new position. Charles Enzian, formerly employed by the Government in the Department of Mines, has been appointed mining engineer of the Shenandoah and Mahanoy division.

Industrial Notes

Potash.—The Potash Recovery Company, a California corporation formed for the purpose of manufacturing potash and other fertilizing chemicals from distillery waste under a patented process, has been permitted by Commissioner H. L. Carnahan to issue 500 shares of its common stock to H. O. Chute and John D. Spreckels, Jr., in exchange for an exclusive license to use the processes and apparatus covered by the patent and an option for the use of the waste products of Mason Malt Whiskey Distilling Company at Sausalito for a period of five years. It is estimated that \$40,000 or \$50,000 will be required to build a plant and install machinery.

The Hargreaves-Bird electrolytic alkali process, according to the *Mining Magazine*, after many years of vicissitude, followed by a drastic reconstruction of the company and change of control, is now being worked at a profit, at Middlewich, Cheshire.

Italy Considering Further Water Power Development.—Italy's coal supply comes mostly from England, and the shutting off of some of this supply and the

difficulty of obtaining shipments have had the effect of arousing Italy to the necessity of further water power development. A series of royal decrees has been issued creating subsidies and other governmental help for the installation and development of more hydroelectric plants. Italy already has a large hydroelectric development, but she plans to free herself from industrial dependence on any other country for power.

The Braden Copper Co., Chile, is planning an increase in its milling facilities to 10,000 tons daily capacity.

Coating Aluminium.—According to *The Engineer* (London) of Feb. 18, a French metallurgist proposes to give aluminium a coating that will take a high polish by successive baths of boiling lye, cyanide, and hydrochloric acid containing ferrous chloride, followed by nickel-plating. The plating is said to be so perfect that the metal can be rolled into plates, drawn into wires, or hammered into any shape without in any way injuring the film of nickel.

The Central Scientific Co. of Chicago will show at the Urbana, Ill., meeting of the American Chemical Society a new line of DeKhotinsky electrically heated and regulated water baths, drying ovens, incubators, etc.

The Bristol Company, Waterbury, Conn., has issued a pamphlet describing its long-distance electric transmitting and recording system for remote records of pressure, liquid level, temperature and motion.

Compressed Air Meter.—The New Jersey Meter Co., Plainfield, N. J., has issued a bulletin describing its compressed air meter for registering the consumption of tools, machines or apparatus run by air. This meter is known as the toll-ometer, and shows direct the flow of air in a pipe or hose in cubic feet of free air per minute.

The W. S. Rockwell Co., 50 Church Street, New York City, has issued a new bulletin (No. 30) describing furnaces and furnace operations from the standpoint of automatic handling. The bulletin contains a discussion of the problems attending the development of automatic heating.

Determination of Size of Filter Plates.—Messrs. D. R. Sperry & Co., Batavia, Ill., manufacturers of filter-presses, have issued a little circular describing how to quickly determine what size of filter plate to use if the total filtering area is given. By the use of a chart it can be quickly found what size of filter plate should be used to obtain minimum expense and what number of plates in that size are required.

William Gaertner & Co., Chicago, Ill., have issued catalog C, describing Scientia calorimeters and other apparatus for fuel testing. Included in this catalog are descriptions of water-jacket calorimeters, calorimeters for specific heat of solids and liquids, Waterman calorimeter, Bunsen ice calorimeter, and other apparatus including the new improved Scientia gas calorimeter.

The Raymond Bros. Impact Pulverizer Co., Chicago, Ill., has issued a new catalog, No. 12, describing grinding, pulverizing and air-separating machinery. The catalog, which is nicely illustrated, includes a description of a new smaller size pulverizer which uses 5 hp. and produces from 200 to 1000 lb. per hour, depending on the material to be pulverized.

The American Synthetic Dyes, Inc., announce the removal of their general offices to the Adams Express Building, 61 Broadway, New York.

Foreign Trade Under the New Tariff.—Secretary Redfield has transmitted to the Senate a detailed statement of the results of the Underwood-Simmons tariff act as reflected in the foreign trade of the country up to the time the war started in Europe. The statement was prepared in the Bureau of Foreign and Domestic Commerce in response to a Senate resolution of Jan. 17, 1916, calling upon the Secretary of Commerce for information in regard to trade under the present tariff. The report is printed as Senate Document No. 366. It contains information regarding the value of imports, exports, and import duties under the present and the two preceding tariff acts; the value of imports, compared with the value of domestic production, and the expenditure for wages in each industry before the outbreak of the European war; and the imports and exports of leading manufacturing countries during recent years.

The Vanadium-Alloys Steel Company of Pittsburgh, Pa., has just issued two folders descriptive of the Vasco Choice and Vasco Non-shrinkable grades of tool steel.

Japanese Regulating the Dyestuff Market.—According to *Commerce Reports* a number of well-known dye merchants of Tokyo, Osaka, and Nagoya have formed a dyestuffs trust, called the Kokuryu Kai, with offices at Osaka, with the object of preventing speculative transactions by amateurs and of regulating the market when the inevitable slump comes, either at the end of the war or earlier. The production of aniline dyes is rapidly increasing. The manufacturers still keep secret the monthly output of their plants, but, according to the *Japan Mail* of Feb. 25, 1916, the monthly production of aniline oil at different works now exceeds 60,000 lb. (a rate of 360 short tons per annum).

Standard Density and Volumetric Tables.—A revised edition of its Circular No. 19 on "Standard Density and Volumetric Tables" has just been issued by the United States Bureau of Standards. It contains tables for use in measurements of density and volume of such liquids as water, alcohol, sugar solutions, petroleum oils, etc., and special tables for use in the calibration of glass volumetric apparatus and hydrometers. In the new edition the tables have been rearranged and several new ones added. Copies may be obtained free by persons interested upon application to the Bureau of Standards, Washington, D. C.

The C. F. Burgess Laboratories, chemical engineers, located at Madison, Wis., have increased their capitalization to \$100,000. The officers are C. F. Burgess, president; Vrooman Mason, vice-president; W. B. Schulte, secretary and treasurer. The Chicago office is located in the Harris Trust Building. Duncan Keith, manager.

Magnetic and Mechanical Properties of Steel.—The Bureau of Standards has just issued a bulletin (Scientific Paper No. 272) on the "Correlation of the Magnetic and Mechanical Properties of Steel," by Charles W. Burrows. The paper is a review of the work done in correlating the magnetic and mechanical properties of steel. Among mechanical properties that have been studied in connection with the magnetic characteristics are hardness, toughness, elasticity, tensile strength and resistance to repeated stresses.

New Chemistry Building for Throop College.—The contract has been let for a new chemistry building for Throop College of Technology, Pasadena, Cal., to cost \$60,000. It is expected that the building will be complete in time for the opening of the fall term this year.

The building will contain a research laboratory of physical chemistry to be under the direction of Dr. A. A. Noyes, who will spend half of each year at Throop College and half at the Massachusetts Institute of Technology.

New Building Construction at University of California.—University building bonds of the value of \$1,800,000 have been approved by the people of California for new buildings at the University of California. The money will be subdivided as follows: \$700,000 for Benjamin Ide Wheeler Hall, a classroom with capacity of 3500; \$525,000 for completion of the library, the present part of which cost \$840,000; \$350,000 for a second group of agricultural buildings; \$160,000 for the first unit of a group of permanent buildings for chemistry; 70,000 for new unit for heating and power plant, the balance for furnishings and equipment.

The University of Kansas, chemical engineers, held a joint meeting with the Kansas City Section of the American Chemical Society on March 31 at the University, in Lawrence, Kan. Among the speakers were Prof. W. A. Whitaker, who contributed opening remarks; Mr. George Belchie, who spoke on "Flotation"; Mr. E. H. Burch, who spoke on "Zinc Smelting"; Dr. Roy Cross, who spoke on the cracking of petroleum, and Mr. C. A. Wright, who spoke on losses and problems in the Joplin district.

Book Reviews

Coal and Coke. By Frederick H. Wagner, M. E. Octavo (15 x 23 cm.), 431 pages, 136 illustrations. Price, \$4.00 (17/). New York: McGraw-Hill Book Company, Inc.

Part I, treating of coal, is only one-fourth of the book, and is principally a short treatise on the raw material of coke manufacture. It is a well-written but brief summary of the subject.

Part II, treating of coke, is the other three-quarters of the book. It is a first-class up-to-date discussion, in great detail, of the present methods of manufacturing coke from bituminous coal, valuable not only for the student but for the scientist and the practical man in the business.

We do not see any mention of "peat coke," which is successfully made in Europe. The book is otherwise very complete and satisfactory.

* * *

Applied Electrochemistry and Welding. Part I: Applied Electrochemistry, by Chas. F. Burgess, 83 pages. Part II: Welding, by Geo. W. Cravens, 132 pages. Well illustrated; price \$1.50. Chicago: American Technical Society.

These are in reality two separate books, bound together so as to make one respectable volume. Professor Burgess discusses electrolysis, electroplating, decomposition of salt solutions, fused electrolytes, electric furnaces, and electric discharge in gases. Although very limited as to space, yet there is a large amount of very useful and well-chosen information, enlivened by many collateral remarks, compressed into Part I. Almost any electrochemist will find something new in it to interest him.

The treatment of welding, by Mr. Cravens, is comprehensive and practical. A large part of it is electric welding, but the other methods are properly described. Numerous fine illustrations are shown up well by the thick calendered paper used.

The book as a whole is a useful and very creditable work.

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Two Chemical Society Meetings

The day of the chemist in shaping the future of this country is at hand. This was the keynote of the meetings of the American Chemical Society at Urbana-Champaign and of the American Electrochemical Society at Washington. At Urbana the duty of the universities in the evolution of American chemistry was duly emphasized, and this spirit was typified in the dedication of the new Chemistry Building of the University of Illinois. At Washington the greatest stress was laid on the co-operation between chemist and engineer, and on their common duty in economic and legislative matters. This spirit was typified in the water-power conference of the American Institute of Electrical Engineers, to which the American Electrochemical Society was invited, and in the latter society's discussion on Niagara Falls power. The same idea is the basis of the formation of a Public Relations Committee of the American Electrochemical Society, consisting of the president of the society, as chairman, and all the past-presidents of the society. It will be the duty of this committee to act in an advisory capacity with Congressional committees and at hearings on public matters. As the retiring president, Lawrence Addicks, remarked, this solves a problem little recognized by engineering and scientific societies but very real: what to do with the ex-presidents.

The Rail Tonnage

Rail production in the United States in 1915 was 2,204,203 gross tons, the tonnage exceeding that of only two years, 1908 and 1914, among the 16 years preceding. The output was only 3 per cent greater than in the remarkable year 1887, which has easily held the record to date for the largest railroad mileage constructed. The domestic consumption of rails in 1915 was indeed 17 per cent smaller than in 1887, for in that year there were imports of 137,830 tons and exports of 549 tons, while in 1915 there were imports of 78,525 tons and exports of 391,491 tons, making the apparent consumption 2,276,921 tons in 1887 and 1,891,237 tons in 1915.

The relative smallness of the rail demand in very recent years has been due to the small mileage of new track constructed. In 1887 there was 12,984 miles of new main line track laid. Some later years, while showing relatively small activity in the pushing forward of new railroad line, have shown heavy construction of subsidiary track. In 1915 there was only 933 miles laid of new main line track, with 65 miles of second, third and fourth track, according to the Railway Age Gazette compilation. It requires 157 tons of rails to lay a mile of track in 100-lb. rails.

There was a period, culminating in 1906, with its production of 3,977,887 tons, the record output, in which rails that had been in track for many years had to be replaced because they started to wear out rapidly when subjected to the pounding of the much heavier locomotives coming into vogue, together with the steel freight car. Even in 1906, however, there was nearly as large a tonnage produced of rails over 45 lb. and under 85 lb. as of heavier rails. Since then there have been further increases in the weight of rolling stock, and the 1915 rail production, other than the "light rails" under 50 lb., comprised 26.6 per cent 50-lb. but under 85-lb., 38.1 per cent, 85-lb. but under 100-lb., and 35.3 per cent 100-lb. and over. If these heavy rails are demanded in such proportions it seems reasonable to infer, so great is the ubiquity of the heavy locomotives and cars, and so great is the damage done by them to rails of less than proper weight, that there will in future be a great demand for the purpose of replacing a large proportion of the rails now in service, not because these rails would wear out quickly if subject to the traffic conditions existing at the time they were laid, but because they cannot give good service under the more modern conditions.

The rail production statistics, presented in the detailed form long followed by the Bureau of Statistics of the American Iron and Steel Institute and its predecessor the American Iron and Steel Association, make rather interesting reading. It was not until 1908 that the production of open-hearth rails exceeded one-tenth the production of Bessemer, but in 1914 the production of Bessemer was only one-fifth that of open-hearth. In 1915 only 1 per cent of the rails 100 lb. and heavier was Bessemer, while even in light rails the proportion of Bessemer was only one-fourth.

Statistics of electric steel rails began with 462 tons in 1911, the output rising to its maximum, 3455 tons, the next year, while 2436 tons was produced in 1913 and 178 tons in 1914, not a ton being reported for 1915. It may be, however, judgment is suspended until time has elapsed for a complete tryout of the experimental rails.

The titanium-treated steel rail reached its height in 1910, with 256,759 tons, the quantity dwindling rapidly until it was only 21,191 tons in 1915. Rails otherwise alloyed amounted to 13,450 tons in 1909, the first year for which such a report was made, the tonnage decreasing to 3779 tons in 1915, in all of which the alloy metal was manganese.

An item from which we are indisposed to draw definite conclusions is that the production of renewed rails, from new seconds, defectives, etc., was maximum at 43,793 tons in 1913, decreasing to 9129 tons in 1915, these tonnages constituting 1.31 per cent and 0.43 per cent respectively of the total tonnages produced. The production of rails rolled from old rails, included in the general production statistics, has not shown any remarkable variations, and amounted to 102,083 tons in 1915.

Cost-Accounting

In this issue we commence the publication of a series of articles on cost-accounting, with special reference to the construction, operation and maintenance of a copper smelter. The methods of accounting presented were developed by the author for use in the reconstruction of one of our large western smelters, and may, therefore, be regarded as highly practical from the engineer's viewpoint.

There is a vast difference between the kind of cost data desired by the engineer and by the auditor. Each works from a different basis and has a different object in view. The engineer wants unit costs for different kinds of work, and segregates his results in units of labor and material. The auditor, however, is satisfied if he knows the cost in dollars and cents, and aggregates the items that refer to a particular job. The results of both are important and necessary, but of little value each to the other.

The importance of unit costs to the engineer can scarcely be over-estimated in their relation of efficiency. Once determined, they form a standard for comparison, not only for similar work at different places, but during successive periods of time at the same place and on the same job. They can be properly gathered only by the engineer because he alone appreciates their value and knows how he wishes them expressed. It becomes necessary to establish a system of recording all items and securing the cooperation of employees and staff in formulating information so that costs can be obtained therefrom.

The present series will cover construction, operation, repairs and renewals of plant and metallurgical accounting of metal in process during operation. The scheme of gathering and recording data will suggest applicability to lines of metallurgy other than smelting and should prove of general value.

Steel Industry Moving Rapidly

The very fact that the men in the steel industry are so busy tends to prevent their recognizing what rapid strides are being made in the industry as a whole, by reason of their working so hard. If one could plot the activity, measured by the volume of new construction and the mechanical and metallurgical adaptations being made he would undoubtedly find the curve at its highest point at the present time, even though the period covered started with the very beginning of the industry, and we believe that would be the showing even though the curve were plotted not from the absolute values of the activity but from the activity divided by the tonnage hitherto produced. The things being done are big even for a big industry.

Some time the history of this period in the American steel industry may be written, though such a work could be compassed only by the collaboration of many workers, and if ever it is written it will prove very interesting. Here there can be but the roughest sketch, and so great is the field that might be covered that even an orderly presentation of what can be mentioned is impossible.

In tonnage the blast furnaces have given a spectacular performance. In the spring of 1913, with apparently practically all the available capacity in operation, production reached a rate of 34,000,000 tons per annum. Since then only eight new blast furnaces have been completed, with a capacity of a trifle more than a million tons, and yet the production of pig iron has reached a 40,000,000-ton rate. Only a few furnaces have been rebuilt and enlarged, and it is a conservative estimate that of the 6,000,000-ton increase in the productive rate more than one-half has been attained by better practice and by changes in the lines of furnaces as they have been relined. By far the most conspicuous change is the enlargement of the hearth, whereby a greater tonnage is obtained from a furnace of the same height and maximum diameter without a corresponding increase in the coke consumption. In many instances a material increase has occurred in tonnage with no increase at all in the capital investment.

In a trifle more than fifteen years the number of retort coke ovens in the United States has increased from 1000 to 6000, but at the present time more than 2000 are under construction or are definitely projected to be built as soon as possible. As the capacity of the new ovens will be somewhat greater than the average of the existing ovens, the by-product coking capacity is increasing at the rate of more than one-third in the average period of time required to build such plants. To a limited extent this activity may be ascribed to a desire to win the by-products, particularly benzol, but it is to be noted that only a small proportion of the benzol obtainable at existing plants has thus far been produced. The proportion of benzol produced to by-product coke made is increasing. The present activity in by-product coke construction is due chiefly to the fact that capital is readily available. The industry wanted the by-product plants before this.

Some remarkable results are being achieved in the burning of powdered coal, the most spectacular of the adaptations being to an open-hearth steel furnace, without the use of regenerators, as recounted recently before the Franklin Institute by C. J. Gadd of the American Iron & Steel Manufacturing Company. The indications are that where coal must be burned in future it will be burned in powdered form.

It is only about three years ago that the first steel rolling mill was operated by current purchased from a public service corporation, but since then several such arrangements have been made. This is a development of the steel industry, but an achievement of the central power station, and one that reflects no small credit upon the engineers in various lines of endeavor who have contributed towards reducing the cost of converting the energy of coal into electrical energy.

Let us pause a moment to observe that all the developments we have mentioned, the change in blast furnace practice, the building of retort coke ovens, the use of powdered coal and the purchase of central station current for driving rolling mills, are attended by a saving in fuel. The typical ton of coal is being made to do more and more work.

The steel metallurgical problems have been numerous and very important. What has been done to conserve ferromanganese, when it is so scarce, and accomplish partly by other means the results desired, cannot be told by this time.

A symposium of what has been done along this line would undoubtedly prove very interesting, but cannot be secured at this time.

Before the war broke out American steel works managers thought they had their hands full in endeavoring to meet the various exacting requirements, chemically and physically, of American engineers. Suddenly they were faced with specifications of French, British and Russian engineers, each naturally different from those of American engineers, different also because the purpose to be accomplished lay not in pursuit of the arts of peace, and finally very exacting because the steel had to fill the two desiderata, not necessarily consistent with each other, of being safe in the hands of the buyer and destructive when delivered to the enemy. The varied and complex problems presented might have been regarded as impossible if proposed in normal peace times.

The production of so much "war steel" with its heavy cropping of ingot and billet, as well as the turning and boring of a large tonnage of steel rounds for the manufacture of shells, has produced an enormous tonnage of scrap or discard steel, for which employment has had to be found. The tonnage of steel turnings finding their way to the blast furnace is doubtless larger than ever before. The first discards in the steel mill furnish heavy melting steel scrap, while the second discards, in the form of large billets, have kept the mills and brokers busy finding customers for steel of a description they would never order if they had the choice. The supply of scrap, proportionate to the total tonnage of finished steel produced, is undoubtedly much larger than in normal times, but nevertheless three duplexing plants are being built, one of these, at Donora, representing the addition of converters to an existing open-hearth plant, while the other two, at South Chicago and Gary, are plants being built from the ground up, with converters and tilting open-hearth furnaces. Besides these duplexing plants there are many straight open-hearth furnaces being built.

Even from this brief and necessarily very fragmentary survey of what is going on in the steel industry it can readily be seen that the men who are doing the work have been and are very busy indeed, and it should be observed also that they are laboring under the greatest disadvantages. Deliveries of nearly everything, raw materials, current supplies and machinery, are very hard to get, and labor is scarcer than ever before in the history of the American steel industry. A general wage advance averaging more than 10 per cent was made effective Feb. 1 and yet another advance of about the same amount is authorized for May 1. Although representing but a three months' interval this second advance may not be the last.

These are certainly stirring times for the American steel industry.

Readers' Views and Comments

The Available Hearth Heat of the Blast Furnace

To the Editor of Metallurgical & Chemical Engineering
 SIR:—I have felt, ever since I began writing the articles on the blast furnace, that the result would be better if they elicited criticism from competent sources. I am, therefore, greatly obliged to Dr. Feild for his letter. The thermal theory required more time and hard labor than any other two articles, but the result is not satisfying to me, and, naturally, not to others.

Dr. Feild's criticism may be divided into four parts for convenience:

First.—His approval of the critical temperature theory.

Second.—His assertion that the second law of thermodynamics has nothing to do with the case.

Third.—His statement that my method of treating the subject is unfortunate, because it is not that of the physical chemist.

Fourth.—His descriptions of the mistakes in my figures, and the consequent incorrectness of my chart of hearth heat.

Let us consider these subjects in this order:

First.—Dr. Feild's approval of the critical temperature theory is gratifying; the theory has already had the approval of a large number of practical furnace-men and scientific metallurgists. I am sure that all its friends will be glad to see the approval of a physical chemist added.

Second.—Dr. Feild's assertion that the critical temperature theory has no relation to the second law of thermodynamics leaves me rather at a loss.

I gave a definition of the second law of thermodynamics based on a fairly wide study of that subject as follows:

"The proportion of a given quantity of heat which can be utilized for conversion into work depends upon the temperatures at which the heat is applied and discharged."

This is certainly true in heat engines. In fact, it is a crude statement ("from the point of view of the engineer," I admit) of the general law that the utilizable energy in any case is the product of the quantity of energy by the availability factor.

In the case of the blast furnace hearth, the heat can certainly be considered as applied at the theoretical combustion temperature, and is discharged at the critical temperature. This fact is the critical temperature theory which receives Dr. Feild's official sanction.

The same general law can be expressed in both cases (the heat engine and the blast furnace) by the same mathematical expression

$$Q \frac{T_1 - T_2}{T_1}$$

This may be due merely to a "superficial resemblance"; from the point of view of the physical chemist, it evidently is.

My suspicion is that my treatment of this subject is too simple for physical chemists. I believe if I had developed these facts through a couple of dozen differential equations, they would understand the matter as most other mortals do.

Third.—Dr. Feild thinks my treatment of the subject and my methods of calculation are unfortunate, apparently, because they are those of the engineer rather than those of the physical chemist.

As to the fact at least Dr. Field and I are in entire agreement. The treatment used is that of the engineer.

But is this a misfortune? My ambition never soared to the point of desiring to instruct physical chemists in anything, but I venture to hope that my experience and investigations may be of use to young engineers interested in the blast furnace.

For this purpose, as regards the thermal theory, I have not found it necessary, desirable, or even convenient, to use any mathematics beyond the simplest arithmetic, while the physical chemist accomplishes the same purpose, in its simplest phase, only by the use of differential and integral calculus.

Dr. Feild says it is "very simple" to calculate the case of moist blast by the same method. I invite him to publish the complete expression for doing it, taking due account of the fact that the nitrogen present decreases and the hydrogen increases as the water vapor increases. Then I will ask the editor to take a ballot among his readers to see whose treatment they prefer, Dr. Feild's or mine, even with its admitted imperfections.

Fourth.—Dr. Feild's statement as to the errors of my calculations and chart.

Dr. Feild states that my method is substantially correct, but my results are entirely in error because I have used wrong constants. He is right as to the figures quoted from my paper of eleven years ago, but while he has referred to my table of data converted from those of Professor Richards on page 791, he has apparently overlooked entirely the adjacent paragraph:

"I have recently recalculated the hearth heats in accordance with these (Professor Richards') more accurate data for the chart Figure 1. This is substituted for the original Figure 1, as the results it gives are the same in principle but somewhat more accurate and the range of conditions covered is wider." There is, therefore, no error in my chart due to the use of an incorrect specific heat for carbon.

Where, then, does the discrepancy arise between my figures and those of Dr. Feild, as shown in his modification of my diagram?

It comes in part from the fact that I purposely ignored the fact, of which I was well aware, that the heat of reaction is different, in this case higher, at a high temperature than it is at room temperature. This I did because I regarded the difference as insignificant in comparison with the larger quantities involved and because I did not wish to add to the very serious labor of making the calculations on which Figure 1 is based. This was a mistake, for the error is a considerable percentage of the total in the case of the hearth heat, though unimportant in regard to the shaft heat.

But even with this correction, my curves do not agree with those of Dr. Feild.

What is the cause of this further discrepancy? I regret to say that it appears to be due to errors in Dr. Feild's calculations. I have calculated from Professor Richards' data the heats of reaction given in Dr. Feild's table 1 and I find his results to be in error as shown in Table I.

The figures in the right-hand column were calculated with a slide rule and are liable to be in error to the extent of one or two units, but hardly more.

These were calculated from the original data in Professor Richards' book and checked by my table of converted data based thereon.

TABLE I—CRITICAL TEMPERATURE

Degree F.	Degree C.	Heat of Reaction B.t.u. Per Lb.	
		Of Fixed Carbon Dr. Feild's Results	Correct Results
2,192	1,200	4,674	4,570
2,372	1,300	4,707	4,596
2,552	1,400	4,738	4,623
2,732	1,500	4,772	4,649
2,912	1,600	4,805	4,674
3,092	1,700	4,835	4,699
3,272	1,800	4,865	4,724
3,452	1,900	4,897	4,749

The figures in Dr. Feild's table 2 are also in error and to a greater extent than his table 1. I have not recalculated all the data therein because they are of no use in calculating hearth heats, but the correct figure for 1000 deg. C. (1832 deg. Fahr.) is 2708 B.t.u. instead of 2538, and for 1900 deg. C. (3462 deg. Fahr.) is 5485 B.t.u. instead of 5027. I have already given at some length, later in the article, the best analysis I had data for, as to the utilization of the hearth heat, and while that analysis is admittedly in error to the extent of my error of omission in calculating the hearth heat, I would obtain more benefit from Dr. Feild's criticism of that than of my article of eleven years ago.

In conclusion I would like to make it clear that I do not regard the article on thermal theory as logically complete in all particulars or as being, by any means, the last word on the subject. I have merely endeavored to put into permanent form for the use of others the results of calculations and of practice, covering almost twenty years, in the hope that they may serve as stepping stones to further our knowledge of the subject. It is inevitable that my conclusions should be erroneous in part, and I shall welcome criticism which furthers the ends of important truth, but I do not believe those ends are furthered to their maximum extent by criticism which merely and unnecessarily substitutes calculus for arithmetic, which overlooks important explanations in the article criticised, and finally, which "corrects" errors with scientifically derived tables that are not arithmetically correct. J. E. JOHNSON, JR.

New York City.

Summer Meeting of American Institute of Chemical Engineers

The eighth semi-annual meeting of the American Institute of Chemical Engineers will be held in Cleveland, Ohio, from Wednesday to Saturday, June 14 to 17, inclusive.

American Iron and Steel Institute Meeting

The American Iron and Steel Institute will hold its May meeting at the Waldorf-Astoria, New York, on May 26 and 27. A few of the papers follow:

"By-Products Recovered in the Manufacture of Coke," by W. H. Childs, president Barrett Company.

"The Electric Furnace in Steel Manufacture," by Dr. John A. Mathews, president Halcomb Steel Company.

"Rail Manufacture," by Dr. John S. Unger.

"The Distribution of Materials in the Blast Furnace," by G. W. Vreeland, superintendent blast furnaces Carnegie Steel Company.

Meeting of New York Section of A. I. M. E.

A very interesting and enjoyable dinner meeting of the New York Section of the American Institute of Mining Engineers was held at the Columbia University Club on Friday evening, April 21. The subject for the talks of the evening was "Fakirs We Have Met," and

some very ingenious schemes were divulged. There was a wide variety of stories and they were fully appreciated by the large number of members who were present. The chairman, David H. Browne, presided, and the speakers were A. R. Ledoux, Sidney Jennings, George F. Kunz and E. Gibbon Spillsbury.

Flotation Meeting Program

A joint meeting of the New York Sections of the American Institute of Mining Engineers and of the American Electrochemical Society will be held on May 12, 1916, in the Rumford Hall, Chemists Building. The "how" and "why" of flotation will be discussed in two papers by Geo. D. Van Arsdale and Wilder D. Bancroft respectively, and a spirited discussion is expected to follow. The meeting will be preceded by a dinner. Both sections will hold their elections of officers for the coming year.

Faraday Society Meeting

Discussion on High Temperatures in the Laboratory

The seventy-eighth ordinary meeting of the Faraday Society was held on Wednesday, March 15, 1916, at the Institution of Electrical Engineers, London, W.C. The meeting was devoted to an informal discussion on "Methods and Appliances for the Attainment of High Temperatures in the Laboratory." Sir Robert Hadfield, president, was in the chair, and the discussion was opened by Dr. J. A. Harker, of the National Physical Laboratory.

Sir Robert Hadfield, in introducing the subject under discussion, referred to the difficulties experimenters used to labor under in trying to melt small quantities of metals like steel or copper in the laboratory before modern appliances, such as would be described by Dr. Harker, were devised. He then went on to emphasize the importance of laboratory high-temperature furnaces in connection with the standardization of pyrometric determinations, and he gave a short historical sketch of developments in pyrometry, beginning with Wedgwood's work in 1782, and referring particularly to the work of le Chatelier and Osmond in France, and W. Siemens, Roberts-Austen and Callendar in Great Britain, coming down to the more recent work carried out by some who would take part in the present discussion.

Dr. J. A. Harker, in opening the discussion, said his object was to draw attention to some of the more difficult points in this subject. He dealt almost exclusively with the carbon resistance furnace. The difficulty with this type of furnace was to obtain carbon of the proper qualities, and it was satisfactory to know that in England the (British) General Electric Company had a stock of carbon tubes for this purpose. Carbon for electric furnaces had a very variable specific resistance from one sample to another. Graphite had, roughly, one-fifth the specific resistance of carbon. It was much more uniform, and contained very much less inorganic impurities. It differed chiefly in that its hardness was of quite a different order, and it could be cut on a machine like hard wood. With carbon, on the other hand, the lathe tool lost its edge directly, and it was impossible to cut rings or patterns, unless the specimen was particularly tractable. The temperature co-efficient of carbon was practically nil for the first part of its running up, and then became strongly negative. Provision had to be made for the fact that the voltage had a tendency to fall rather than rise, and the current con-

sequently to go up. For certain purposes when using graphite it was better not to make a plain, straight conductor, but to make it into a spiral or zig-zag.

One of the difficulties was that at high temperature a neck was likely to form just inside the clamps, and irregularities of heating took place, which resulted in a poor life, and there was a great tendency for the whole thing to break in cooling off. Provision had also to be made for the carbon monoxide formed in the furnace to be quickly burned. The material of which most tubes were made contained inorganic matter up to about $2\frac{1}{2}$ per cent, while a thoroughly good specimen contained about $\frac{1}{2}$ per cent. This could nearly all be burnt out by heating quickly to 1800 deg. or 1900 deg.

The need for completely inclosing the carbon furnace was very great, and at the (British) National Physical Laboratory some years ago Mr. Eden built the walls of such a furnace of reinforced concrete, which was considerably better than bricks for preventing the carbon monoxide from getting into the atmosphere. At the same time for laboratory purposes it was essential to have an apparatus of not quite so permanent a character, and in this connection he exhibited a new form of furnace which Mr. Eden had made. The difference between a good and bad type of furnace was all in the small details. In the carbon tube furnace, for instance, it was not at all easy to keep the thing working properly unless the ends were water-cooled. No conductor having a large current density with a big temperature gradient could go on working very long and maintain steady conditions. Sooner or later it caused a big increase in the voltage drop where the copper conductor joined on to the ends, and trouble followed, such as great local heating at the contact. In this new furnace, water cooling had been applied not only to the electrodes but also to the ends, because the furnace was inclosed in an aluminium bomb arrangement, and the ends, which were bolted onto the bomb, were fastened by a packing ring, which had to be kept cool.

The maintenance of the insulation of the carbon tube was also important. One way was to have another tube round the carbon tube with an air space between, but for high-tension work this was thoroughly bad. He had found the simplest and best thing was to use the grade of lamplblack used by paint makers, filling up all the space around the carbon tube for a radial distance of 3 in. This has been found to be by far the most satisfactory material for ranges of temperature above 1500 or 1600.

Another point in connection with the new furnace was the important one of economy. It was necessary to obtain high temperatures with small power, and in order to get over this satisfactorily a small portable transformer had been made, which could be used in the laboratory. There were eighty turns of primary made up in the simplest way, and three secondary turns capable of being coupled in series or parallel. The primary was split so as to be used at 300 volts and downward, and currents could be obtained up to about 1000 amp. With the insulating soot which he had mentioned, the 1 kw. which was necessary to maintain the temperature of 2000 deg. C. in the furnace only heated the outside wall to something over 100 deg. C., so that there was no need for elaborate precautions.

Sir Robert Hadfield pointed out that one of the furnaces exhibited was to be sent to his works at Sheffield.

Dr. Harker added that Messrs. Hadfield's were going to do with that furnace just what had been done with it at the National Physical Laboratory, namely,

standardize optical pyrometers. At the National Physical Laboratory there was a furnace like the one shown mounted beside a bench, on which all pyrometers for verifications were put, and slid along, the indications being compared with those of the standard.

Mr. R. S. Whipple dwelt on the difficulties he had experienced with optical pyrometers owing to the fact that many optical materials came from Germany and that it was difficult to get truly monochromatic glass. With regard to Dr. Harker's furnace, what struck him was the way the temperature could be maintained constant. He described some electric furnaces he had seen in America used for gear-hardening. Thermocouples passed through the furnace on to the work, which was simply brought up to the recalcrescent point, as indicated in a Northrup recording pyrometer, and then taken out and quenched. It was a beautiful technical application of scientific phenomena.

Dr. W. Rosenhain said the problems mentioned by Dr. Harker became more difficult when one dealt with a larger space, in which it was desired to melt things. The application of electrical heating for making optical glass was at present under investigation, but he would refer to some general difficulties in the use of high-temperature furnaces. One was the presence of carbon compounds; he wanted a furnace as tractable as Dr. Harker's, which would be free from carbon. On a small scale a tungsten wire vacuum furnace was effective, and he had melted pure iron (1525 ± 5 deg. C.) in such a furnace. But the tungsten became brittle, and a fresh winding was necessary for each run. Granular tungsten resistors might be used, and so might a carbon resistance furnace with an inner tube, an indifferent gas between the two and a slightly oxidizing gas in the inner space. The drop of volts between metal clamps and electrodes in electric furnaces became serious with large currents. He suggested coating the carbon with copper, aluminium, or iron, as the case might be, by the Schoop spray process, burnishing the coating to give a good metallic contact.

The possibilities of gas furnaces were often overlooked. He described two types which he had found useful—the Ségar furnace, and one they had evolved at the National Physical Laboratory. The former, which required a 30-ft. chimney, worked quietly and steadily; but for high temperatures he used a special type of injector burner for use with compressed air at 100 lb. per square inch, and with this temperatures up to 1800 deg. C. were obtained.

Mr. C. R. Darling remarked that the furnace first described would be very useful for laboratory purposes for melting small quantities of metals. He pointed out some of the drawbacks of platinum-wound furnaces. In furnaces of Dr. Harker's type he had found magnesia bricks satisfactory for outside lagging. Up to 1000 deg. C. furnaces wound with nickel-chrome wire gave good results. A furnace one foot long, using an inch tube, consumed only $\frac{1}{2}$ kilowatt.

Mr. H. G. Lacell agreed as to the value of nickel-chrome winding. A kieselguhr tube wound with ribbon of this material could be rigged up in a few minutes. He had given up gas-heating for any temperature below 1000 deg. C.

Mr. H. A. Kent had been using a lime furnace for melting platinum and iridium, working beyond 3000 deg. C.; but he had recently obtained excellent results with a crucible of pure zirconia, using an oxy-hydrogen cyclone burner. He hoped it would be pos-

sible to make here pure zirconia in granular form; if so, almost any temperature could be obtained with surface combustion.

Mr. A. J. Webb said he had obtained good results with the Brayshaw burner, with which he had accidentally melted a large piece of platinum with an air pressure of only 20 lb. and the ordinary gas supply. Mr. Kent had introduced a good burner similar to Dr. Rosenhain's, in which gas was blown in at the side.

Mr. S. N. Brayshaw said it was possible with his burner to melt small quantities of platinum with 3 lb. air pressure. Noise was the essence of a good burner; the gas and air had to be sent into the furnace not only mixed but in a state of violent agitation. The turbulence of the explosive mixture in gas-engine cylinders was a parallel phenomenon. He gave a descriptive sketch of the burner which bore his name.

Dr. H. C. Greenwood thought there was nothing better than charcoal for insulating carbon tube furnaces, and he held a brief—for many purposes—for the rougher type of furnace built of bricks and charcoal. He described a simple device for the calibration of pyrometers. With regard to large furnaces, something was wanted between the arc furnace and the steel-melting furnace, and where a completely reducing atmosphere was not required the gas furnace had great possibilities. He had melted 100 lb. of German silver at 1200 deg. in a resistance furnace with a number of resistors in series.

Mr. F. Twyman suggested the use of gelatine screens as a substitute for red glass in optical pyrometers.

Dr. W. Rosenhain remarked here that at the National Physical Laboratory they were experimenting with zirconia, and he hoped something would emerge that would be generally available.

Sir Robert Hadfield believed that very high pressure blasts would have a great future. Bessemer had worked on them at one time, and he was glad the idea was being taken up again.

Dr. J. A. Harker, in reply, said that until they had zirconia tubes, alundum could be used as a substitute for carbon where that was unsuitable; but it was more expensive than carbon, and at present it was not gas-tight. He hoped the lampmakers would make squirted tungsten tubes, as they would be extremely useful. In his carbon-tube furnace, to prevent the soot from falling into the spiral groove it was only necessary to wrap filter paper round the tube. Its ash kept the soot from falling. The present uncertain quality of coal gas was a difficulty in gas furnaces.

The Nitration of Toluene*.

BY E. J. HOFFMAN

Trinitrotoluene, the powerful explosive that is being used in enormous quantities in the war in Europe, and is used in smaller quantities in the manufacture of detonators for use in ordinary blasting, is made from toluene, which is obtained as a by-product from the manufacture of illuminating gas, and is also obtained by "cracking" petroleum, the process of manufacture being one of nitration. Various methods of nitrating toluene are in successful use, but the published data regarding them are incomplete. In the course of an investigation at the explosives chemical laboratory of the Bureau of Mines, at Pittsburgh, it became necessary

to work out the conditions under which the best yield of trinitrotoluene could be obtained from a sample of toluene under examination, and a method has been developed which, it is believed, can be satisfactorily applied on a commercial scale to the nitration of any toluene of approximately the same purity as that used.

This toluene had a specific gravity of 0.8659 at 20/4. Fractionated with the use of a Hempel still head, 88.40 per cent distilled between 109.4 C. and 110.1 deg. C., and approximately 97 per cent between 108.4 C. and 110.1 deg. C. Freezing tests made below zero and as low as -91 C. (uncorrected) indicated that the impurities did not exceed 1 per cent.

The method probably most commonly used in the industries for the manufacture of trinitrotoluene involves three separate operations: (a) the preparation of mononitrotoluene, (b) the conversion of mononitrotoluene into dinitrotoluene, (c) the further nitration of dinitrotoluene into trinitrotoluene.

In addition to any other economical advantages this method may possess it would be the obvious method where it is desired to utilize a part of the mononitrotoluene and dinitrotoluene products for purposes other than the preparation of trinitrotoluene. But where the sole object is the preparation of trinitrotoluene and no regard is had to intermediate products except in so far as these may effect the character and quantity of the final product, it would appear desirable to accomplish the nitration in not more than two operations.

For the especial reason that it avoids the actual separation of the dinitrotoluene in the second stage of the nitration, the following procedure was selected as most satisfactory for development: (1) the preparation of mononitrotoluene from toluene, (2) the further nitration of mononitrotoluene to trinitrotoluene.

1. The preparation of mononitrotoluene. The best results were obtained in this stage of the nitration by the use of a mixture of one part by weight of nitric acid of specific gravity 1.42 and two parts of sulphuric acid of specific gravity 1.84, the nitric acid used being 50 per cent in excess of that required theoretically for the conversion of the given weight of toluene into mononitrotoluene. The nitration was accomplished at a temperature of approximately 10 to 30 deg. C. Either the toluene was added slowly, with constant stirring, to the mixed acid, or the reverse procedure of adding the acid to the toluene was followed.

Examination of the respective products showed that the former procedure yields a mixture of approximately 60 per cent mononitrotoluene and 40 per cent dinitrotoluene, while by the latter procedure very little dinitrotoluene was formed. By the former procedure the formation of any considerable proportion of dinitrotoluene could be avoided by the use of only a small excess of nitric acid, but in that case some of the toluene would escape nitration, and other difficulties would be introduced, such as of maintaining the progress of the reaction at a temperature of 30 deg. and the formation of dark reaction mixtures, that often render impossible the separation of the mononitrotoluene from the spent acid by gravity. On the other hand, the use of an excess of nitric acid greater than 50 per cent is to be avoided, as it leads to the formation of a still greater proportion of dinitrotoluene which may separate out in the solid condition.

However, the formation of as much as 40 per cent of dinitrotoluene with the mononitrotoluene was not found to be objectionable, as the total product was to be further nitrated to trinitrotoluene, and for the reason that the temperature could be much more easily controlled, the procedure of adding the toluene to the mixed acid was generally followed. While nitration at

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a maximum of 30 deg. was generally adhered to, the experiments did not show that the yield or character of the product was seriously affected by allowing the temperature at times to rise as high as 50 deg.

When the nitration was accomplished by adding the toluene to the mixed acids, the crude mononitrotoluene product, separated by gravity from the spent acids but not purified, was almost invariably 80 to 83 grams.

2. Preparation of trinitrotoluene from mononitrotoluene. In the main these experiments are included in three series.

Series 1.—In this series of experiments the crude mononitrotoluene was dissolved in 100 per cent sulphuric acid and nitrated with a mixture of equal parts of 100 per cent sulphuric acid and nitric acid of specific gravity 1.5.

Series 2.—The crude mononitrotoluene was dissolved in sulphuric acid of specific gravity 1.84 and nitrated with a mixture of equal parts of 100 per cent sulphuric acid and nitric acid of specific gravity 1.5.

In the experiments of Series 1 and 2, varying proportions of sulphuric and nitric acids were employed, as well as varying amounts of nitric acid in excess of that required theoretically to convert the mononitrotoluene into trinitrotoluene. The yield and quality of the resultant trinitrotoluene product were generally inferior. This appeared to be due, in Series 1, to the fact that in the initial stage of the nitration the acids were too concentrated, while, in Series 2, the second stage of nitration, dinitrotoluene to trinitrotoluene, was necessarily effected with acids that had become somewhat too dilute before the completion of the operation.

Series 3.—In this series of experiments the difficulties encountered in Series 1 and 2 with respect to acid concentration were overcome by the simple expedient of performing the nitration first with weaker acids, then, after decreasing the water content of the resultant mixture by the addition of fuming sulphuric acid, completing the nitration with stronger acids. The temperature of nitration was found to be a factor of great importance. The best yields and the highest grade of product were obtained in those experiments in which the temperature was not allowed to exceed 117 deg.

The results obtained in the investigation lead to the conclusion that the following procedure will give the best results in the preparation of trinitrotoluene.

1. *Preparation of mononitrotoluene*.—The acid used in the first stage of the nitration of the toluene is a mixture of two parts by weight of sulphuric acid of specific gravity 1.84 and one part of nitric acid of specific gravity 1.42, the weight of nitric acid taken being 50 per cent in excess of that required theoretically for the conversion of all the toluene into mononitrotoluene. For 50 grams of toluene, 73.38 grams of nitric acid are used.

To the mixed acid, cooled to 20 deg. or lower, contained in the nitrating vessel provided with apparatus for cooling and stirring, the toluene is added gradually with constant stirring, the rate of introducing the toluene and the cooling of the reacting mixture being so regulated that the temperature does not exceed 30 deg. When approximately 70 per cent of the toluene has been added, the nitration becomes much slower and very little cooling of the mixture is required. When the total amount of the toluene has been introduced and the temperature ceases to rise, the cold water surrounding the nitrating vessel is allowed to run out, while the operation is continued about one-half hour longer. After standing, preferably over night, the spent acids are removed by gravity from the supernatant crude mono-

nitrotoluene, which consists of a mixture of mononitrotoluenes and dinitrotoluenes.

2. *Preparation of Trinitrotoluene from Mononitrotoluene*.

A. The mixed acid used in the first step in the conversion of the crude mononitrotoluene into trinitrotoluene consists of equal weights of sulphuric acid of specific gravity 1.84 and nitric acid of specific gravity 1.5, the nitric acid content being 50 per cent in excess of that required theoretically to convert the calculated yield of mononitrotoluene into dinitrotoluene. For the product derived from 50 grams of toluene, 54.58 grams of nitric acid are taken.

The crude mononitrotoluene is dissolved in sulphuric acid (sp. gr. 1.84) equal in weight to the mixed acid and heated to 50 deg. The mixed acid is added gradually, with constant stirring, for a period of at least one hour, and during this time the temperature should not exceed 100 deg. After all the acid has been introduced, the mixture is heated for two hours at a temperature of 90 to 100 deg.

B. At this point the acids in the nitrating vessel, cooled to about 90 deg., are concentrated by the addition of 15 per cent oleum equal in weight to that of the mixed acid to be used in completing the nitration. If the oleum is added slowly very little rise in temperature occurs.

The mixed acid next used consists of equal weights of nitric acid (sp. gr. 1.5) and 15 per cent oleum, the nitric acid taken being double that required theoretically to convert the above nitration products calculated as dinitrotoluene into trinitrotoluene. On the basis of 50 grams of toluene, 72.78 grams of nitric acid are used.

The mixed acid is added gradually, with continued stirring, while the temperature is allowed to rise up to, but not above, 115 deg. When approximately 75 per cent of the acid has been introduced heating is required to maintain the temperature above 100 deg. A minimum time of two hours should be allowed for the introduction of the acids. When the addition of acid has been completed the heating is continued for two hours longer, maintaining a temperature between the limits of 90 deg. and 117 deg., but not exceeding the latter temperature.

Upon the completion of the nitration the reaction mixture is allowed to cool in a vessel adapted to the subsequent removal of the spent acid. After standing at least 18 hours the crude trinitrotoluene will have separated as a solid cake and suspended crystals. After draining off the underlying spent acid the crude product is crushed, washed first with cold water, and then several times in the molten condition with hot water until free from acid, after which it is dried and tested. If a higher degree of purity is required this is obtained by recrystallization from a mixture of 9 parts by volume of 95 per cent alcohol and 1 part of benzene, or by simply washing well with the cold alcohol-benzene mixture.

The spent acid contains in solution additional trinitrotoluene as well as lower nitration products which may be recovered by precipitation in water—but in practice the spent acid would be used over again after renewal by the addition of fresh acids. By the procedure outlined above a product can be obtained which when washed well with water amounts to approximately 75 per cent of theory and melts at 78 to 80 deg. From the spent acid an additional product can be obtained equal to approximately 8.5 per cent of theory, but which melts at 69 to 75 deg. After washing with the alcohol-benzene mixture the yields of trinitrotoluene become approximately 69 per cent, melting point 79 to 81 deg. and 7.5 per cent, melting point 78 to 81 deg.

The Waterpower Conference of the American Institute of Electrical Engineers

The "water-power conference" held by the American Institute of Electrical Engineers on the afternoon and evening of April 26, 1916, turned out to be one of the most interesting meetings ever held by the Institute. President JOHN J. CARTY in his opening remarks emphasized the professional standing of the Institute and its usefulness as a national institution, and there was no doubt about this point at the end of the whole meeting.

Three papers were presented in the afternoon session, those of Mr. Addicks, Dr. Cushman, and Mr. Stillwell, and two in the evening session, those of Dr. Whitney and Mr. Dunn, abstracts of which will be found below. At the end of each session there was a lively discussion, which became quite spirited in the exchange of viewpoints of electrical engineers and electrochemists, the American Electrochemical Society having been invited to attend this meeting, and quite a number of its members being present. Another pleasing and unusual feature was the presence of a number of members of Congress, and the brief speech of Congressman Smith of Minnesota in the discussion in the evening session. He said Congress needed the help of engineers, but insisted there was a water-power trust, though combination was necessary for water-power developments.

Mr. Rushmore gave an outline of the growth of civilization as characterized by the increasing use of energy. If we withdraw energy from our civilization, everything breaks down. The only way to conserve a water power is to use it; the only way to conserve coal is not to use it. The price which the nation has to pay for the non-development of Niagara Falls power may be expressed in the statement that under present conditions whenever a person looks at the falls it costs the nation something like \$100.

Mr. Stott reviewed the enormous progress made by steam power in the last fifteen years, both first cost and cost of operation having been cut to one-half. In a careful analysis of a certain proposition it had been found that up to a 60-per cent load factor steam is cheaper than water. Mr. Stott saw a possibility for reducing power costs by a combination of steam and water power, with the use of the latter for high load factor loads.

Mr. Lidbury said that if water power is more expensive than steam for low load factors, water power is essentially destined to serve the electrochemical industries. Water power has a big future in connection with the electrochemical industries or none at all. With respect to a suggestion made in the discussion that electrochemical industries should use, if possible, the power of generating stations at times of low load, Mr. Lidbury said this would be economically unsound, since the investment in electrochemical plants per kilowatt is as high as, if not higher than, the investment in the generating station.

Mr. Finney said that the Aluminium Company is developing now 150,000 hp. more; they would be interested in large amounts of power, even if only for ten months a year.

Dr. Baekeland referred to the difficulties of the nitrogen fixation problem. It is a problem with many ramifications. To tackle it is like trying to take a crab out of a bag of crabs—others hang on. He also deplored the wasteful banking methods of this country, due to too many middlemen.

Mr. Dunn referred to a typical case in which 77 per cent of the cost of production of a horsepower-hour for a water power plant represents bond interest on the basis of 7 per cent. To get a 5 per cent bond interest

rate would be decidedly worth while, and is not visionary.

President Carty said that money at low rates could be had for water powers if only legislative uncertainty and restrictions were removed.

Electrochemical Industries and their Interest in the Development of Water Power

Mr. LAWRENCE ADDICKS, in his address on the above subject, emphasized that it is not generally appreciated to what extent electrochemical processes have entered in some phase, at least, of nearly every branch of our industrial life. The electrochemical industries are more important than the public at large realizes; the principal electrolytic processes, electric-furnace processes, and processes involving discharges through gases are briefly reviewed.

Now every one of these industries consumes large quantities of energy. Starting at the bottom, we have the refining of lead at 120 kw.-hr. per ton, and of copper at 300 kw.-hr. per ton. Where diaphragms are used, as in nickel refining, the power rises to about 3000 kw.-hr. per ton. Where insoluble anodes are used for the recovery of a metal from solution, the power will range from 700 to 4000 kw.-hr. per ton, depending upon the metal, the amount of depolarization at the anode, and of course the current density.

Turning now to electric furnaces, an ordinary melting operation, such as casting an alloy or refining steel, generally requires from 600 to 1000 kw.-hr. per ton. In the production of ferro-alloys, which is really a smelting operation, a large amount of energy is consumed by the endothermic reaction, and the power used runs from 3000 to 8000 kw.-hr. per ton of product, depending upon the grade of alloy made. The aluminium furnace requires 25,000 kw.-hr. per ton of product. The electrolytic refining, alkali and aluminium industries require direct current; the graphite, carborundum, melting and ferro-alloy furnaces use alternating current. In general low voltage and high amperage is employed. In the case of alternating current this is readily obtained by the use of suitable transforming units; in the direct-current processes it is customary to connect a sufficient number of cells or furnaces together to obtain a reasonable line voltage. Individual industries in plants of modern commercial size require blocks of energy ranging from 5000 to 50,000 kw.-hr. and it is self-evident that the charge for energy in such quantities is a vital item in the cost sheet. And this brings us to the question of what is cheap power.

Twenty years ago Niagara power was cheap, but in the meantime steam power has made such strides that Niagara and similar water power developments can no longer be considered the exclusive sources of electrolytic power. In so speaking I am of course not considering the very low rates which were made on a few contracts in the early days at Niagara, but of the present rate of about 0.3 cent per kilowatt-hour (\$20 a horsepower-year). With the very high economy of the large turbo-alternator it is quite possible to meet this figure by locating a plant near some of the coal fields. It is therefore idle to discuss any new source of power higher in cost than Niagara.

It is often suggested that electrolytic plants could be operated to advantage on off-peak power. This is seldom practical. In the first place, to shut the power off for several hours in many cases creates very undesirable chemical conditions; then, in most electric furnace processes there is a loss of heat while standing which calls for the expenditure of excess energy upon starting up; and finally, there is the loss of production due to several hours' idleness to be reckoned with, and in this connection it must be remembered that electrolytic plants generally call for heavy investments, the fixed charges on which need every possible ton to divide by. After these handicaps are properly allowed for, it is only in exceptional cases that a mutually satisfactory contract can be made.

And then we have the power contract to deal with. The owner of the water power generally requires that a fixed minimum annual sum shall be paid regardless of consumption. This is naturally a little hard on periods of low output. On the other hand, excess power is apt to be either subject to prior sale or charged at an excess rate, so that the manufacturer has to balance his output on the tip of his nose, so to speak, if he is going to realize the advertised rate per kilowatt-hour.

Next, we have the difficulty that the power is invariably



PHOTOGRAPH TAKEN AT WATER-POWER CONFERENCE OF THE

sold as high-tension alternating current, which imposes various conduction and conversion losses on the purchaser which may easily absorb 15 per cent of the incoming power. The transformers and other apparatus represent a considerable investment, shattering another illusion—that the “other fellow” had to put up all the money. Then in some contracts we mustn’t unbalance the phases or let the power factor run off.

By the time all these allowances are made, the power originally spoken of as 0.3 cent per kilowatt-hour is nearer 0.4 cent, plus a considerable investment, a figure which begins to approach the cost of steam power in the vicinity of New York City, using buckwheat coal; and, as before stated, Niagara Falls is no longer bargain power. This statement leads to a number of questions about as follows:

(1) If cost of power is the great consideration, and Niagara Falls has no longer the cheapest power, why do all the electrochemical industries remain grouped there?

(2) If electrochemical industries have been able to thrive on present power costs, is not the cry for cheaper power merely one for additional profit?

(3) We have in this country a variety of fuel supplies; why are not great central stations established in some of these fields if the resulting power could cost less than water power?

In endeavoring to answer some of these questions, I hope to bring out the main factors which have to be considered in establishing an electrochemical industry.

As to the first question, the cost of power, while important, is by no means the whole, and often not even the controlling factor and Niagara, while an electrochemical center, is not the sole residence of such industries. There are three main factors to be considered in locating such an industry; transportation, labor and power; and in reality power may be placed under the transportation heading, leaving but two. In any industry, raw materials must be carried to the manufactory and the finished product to their markets. As fuel can be carried and electric current can be transmitted, it is evident that the increased cost of power due to such movements is simply a freight item. The moment this is realized the problem does not differ from that prescribed by any other manufacturing operation. Where raw materials are bulky and the product and power used are not, the work will be carried on near the source of the raw material, as in the case of a plant for reducing copper from its ores. Where power or fuel is bulky it may become the controlling factor. In zinc metallurgy, for example, the ores are rich and it takes three tons of coal to smelt one ton of zinc. Zinc smelters are therefore located in the fuel belts. An electrochemical instance is aluminum. Here the ore is carried great distances in order to avoid the transmission of 25,000 kw.-hr. per ton of aluminum produced. Then again, the process may not generally change the bulk of the raw materials, as in refining operations, but

transportation still governs. In electrolytic copper refining the plants are, with a single exception, at tidewater. Here the Western smelters bring the product up to 98 per cent copper. There is but little dead weight in transporting this crude copper, and the silver and gold contents if separated at the smelter would have to travel by express. Also labor and power are cheaper at tidewater, where the market is, than in the Rocky Mountains, where the smelters are. The one exception at Great Falls, Mont., is where an exceptionally cheap water power exists at the smelter, precious metal contents are low, and there is the possibility of considering Western markets and movements via the Panama Canal. Finally, labor is a large item. If we assume that a man earns \$3 a day and that power costs 0.3 cent a kilowatt-hour, the two are of equal importance when an industry uses, on a 24-hour day, 42 kw. per employee. By no means all the electrochemical industries use such a proportionate amount of power. I think enough has been said to show that an appreciation of geographical values is of the utmost importance and that power is of purely relative value.

If we examine the industries grouped around Niagara Falls, we shall find that practically all of them have been created in the last twenty-five years; that many of them use as raw materials such things as carbon, salt, silica, etc., which are obtainable within a reasonable distance; and that they are chiefly those electric furnace operations which rate among the larger power consumers in the electrochemical list. Now, the investment called for in electrochemical plants is generally high, and it can be readily understood that it is a very welcome lessening of obligation in starting a new industry to be able to cut out the money which would be tied up in a private power plant. Also, really low costs on steam power cannot be obtained until a load of about 15,000 kw. is built up. Then, Niagara Falls is in a strong location so far as transportation facilities are concerned. Water transportation through the Great Lakes is at hand and Buffalo is a railroad center. The labor market is also good.

As to the second question, whether 0.3 cent per kilowatt-hour is not low enough to allow any electrochemical industry to thrive, it is simply a matter of competition. Useful as electrochemical products have proved, they are not necessary to sustain life; we got along, after a fashion, a quarter of a century ago before most of them were heard of. We must remember, however, that every one of these products has had to win its way against competition. Graphite and the abrasives have had to compete with natural graphite and emery; aluminum had wood and copper to displace; the alkali products can be produced chemically; the ferro-alloys can be made in blast furnaces; electrolytic refining had fire methods to compete with; electric steel refining replaced the crucible method, and so on. It is quite conceivable that power costs should be so high that the older pro-



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cesses in some cases might revive. On the other hand, electrochemical processes are in their infancy and a decrease in the cost of power is bound to stimulate new lines of production. It is quite within the range of possibility that many of the combustion furnaces now used in metallurgy can be some day replaced by one or another type of electric furnace. Hydrometallurgy, which is closely linked with electrodeposition, has also a large field before it. The question of electrical action on gases is a most promising possibility for development. Take the fixation of atmospheric nitrogen, one of the largest technical problems which this nation has to face to-day. We import large quantities of Chilean nitrate every year. Our only local sources are decomposing organic matter and a small quantity of by-product ammonia salts. Nitrogen is a necessary constituent of fertilizer and is the base of all explosives. The military recklessness of being forced to depend upon imported material for the manufacture of ammunition in these troublous times has recently brought this question very much to the front. There are several methods of fixing the nitrogen of the atmosphere in use abroad. Two of these processes, the oxidation of nitrogen in the electric arc and the conversion of calcium carbide into cyanimid, are suitable for commercial development in this country, and in fact there is already a large plant devoted to the cyanimid industry to guarantee its required supply of explosives in time large quantities of electric power; several hundred thousand horsepower are so used in Norway. The cyanimid process, while chemical, requires calcium carbide, an electric furnace product, as its raw material. As matters stand to-day it may be necessary for the government to subsidize this industry to guarantee its required supply of explosives in time of war. If we had 500,000 hp. available at say 0.15 cent a kilowatt-hour (a common figure in Scandinavia) this great industry would develop at once on a peace basis on account of the fertilizer demands.

As to the third question, our electrochemical industries are either buying from some water-power company or they are generating power themselves from steam. The water-power company naturally sells its output for all that it will bring, with a weather eye on the local cost of steam, and very few industries are large enough to save this profit by operating their own hydraulic plants. Unfortunately most of our high-head water powers, which are capable of development on a small scale and with modern investment, are on the Pacific Coast where markets do not yet exist for many electrochemical products. Most of the latter are of such a nature that they serve only as raw material in manufacturing operations conducted chiefly on the Atlantic seaboard. The time may come when various electrochemical industries will associate in a co-operative power development. In this case the Eastern coal fields will be carefully considered, especially as many of the processes require large quantities of coal for operations entirely apart from electro-

chemistry, such as evaporating or heating liquors, reverberatory smelting, etc. Near a sufficient and suitable supply of water for boiler feed and condensing, and close to the coal mines, a mammoth steam plant could certainly give a lower power cost than now obtainable at Niagara. Perhaps the chief objection to such a scheme would be the present unsatisfactory labor situation in the coal fields.

Then we have the various propositions depending on the use of gas. Natural gas is fast disappearing and can no longer be considered for such a plan. The beehive coke oven, which used to be held up as a glaring example of heat waste, is also rapidly giving place to various retort types. The use of producers supplying gas engines begins to lose its attractiveness as the cost of fuel decreases, and placing the steam plant near the colliery deals a heavy blow to this scheme, which offers low fuel consumption as an offset to great first cost and lack of overload capacity. The by-product coke oven is more attractive, but so far it has been linked up with either the iron and steel industry or the production of illuminating gas, and it is not very desirable to be tied up with another industry and run the danger of being subject to the ups and downs of industrial prosperity in an unrelated field. Then we have our peat deposits, which somehow never seem to receive really serious consideration.

If we knew that there was no hope of getting lower water-power costs, I believe some great central power plant would eventually be established. The two stumbling blocks at present in the water-power question are government control and the great cost of developing low-head powers. One possible way of meeting the latter difficulty is to consider the value of the development from other points of view, such as irrigation, navigation or flood prevention. All the power plant wants is the potential energy in the water.

Summing up, the electrochemical industries have grown to be of great value to this country; they have a fundamental interest in the development of cheap power; they offer nearly ideal power loads of magnitude; they must be located strategically as regards supplies and markets; Niagara power is not cheap enough nor is it sufficient in its present state of development to afford growth to these industries; the industries have so far been hardly strong enough to develop large powers themselves; great expansion should follow the development of cheaper power in accessible locations; and the country is vitally interested in the development of the nitrate industry, which must have very cheap power in great quantity in order to exist. In view of all these considerations, a liberal water-power policy on the part of the government would seem to be a step in the right direction.

Waterpower Development and the Food Problem

In a paper presented by Dr. ALLERTON S. CUSHMAN some interesting facts are given as to the relation of

water power development to our food problem. The great increase in population in the United States has been chiefly in urban districts, while the increase in rural districts has been comparatively small. Consequently there is a larger demand for food without the number of persons engaged in its production increasing accordingly.

Extensive agriculture must ultimately be practiced in an intensive manner, if the food supply of an ever-growing population is to be economically produced. I have no desire to take issue with the Secretary of Agriculture in respect to what he has said about the efficiency of the American farmer. We cannot, however, overlook the fact that European farmers are obtaining higher yields per acre on the self-same soils that supported our own ancestors before their emigration across the seas, perhaps centuries ago, whereas our own agricultural operations began on virgin fields which in too many instances are already run down if not abandoned. If these things are so, lack of efficiency and careless methods of agriculture must be held at least in part responsible for present conditions. It is, however, manifestly unjust to shift the full burden of blame onto the shoulders of the American farmer. Upon capital and government should fall the fuller measure of responsibility in not having long ere this sought methods of providing more abundantly the plant-food requirements of the soil. If it is true that before the war Belgium's crops showed the highest yield per acre, it is also true that the Belgian acres used the highest pro rata quantities of intensive fertilizers. It is at least comforting to learn that the total production in 1914 of our own United States in its six leading cereals aggregated nearly five billion bushels. But in spite of these overwhelming figures, it is foolish to close our eyes and shut our ears to the conditions that have to be met in the face of an ever-growing population and a relative and actual decline in the most highly nitrogenous food products.

The question of an adequate food supply for a growing population resolves itself, in the last analysis, into an adequate plant food supply. Fixed nitrogen, compounds of potassium and phosphates are the principal plant foods needed. For fixed nitrogen we must look to the free nitrogen of the air. This can best be obtained, it appears at present, by the development of water powers properly and economically located and financed for the end in view. In Norway alone about 500,000 kilowatts are engaged in the manufacture of artificial saltpeter. It is important that the water powers be suitably located and the cost of energy low. Up to 1914 more than 80 per cent of all the mixed fertilizer produced in the United States was used east of the Allegheny Mountains. To be practical, electrical water power must serve its own market, and its own neighborhood.

In regard to potash, the extraction from feldspathic and granite rocks by electrolysis presents by no means an insoluble problem. It only awaits cheap power.

Our vast phosphate fields of the South and West are in an immediate danger of exhaustion. We possess very large phosphate deposits which are not directly amenable to the usual sulphuric acid treatment owing to the presence of iron and alumina. These deposits are awaiting an economical process of treatment in which electrochemistry may play an important part.

"It is possible, however, that there are many people in this country who have never yet realized that the potential energy of a flowing river can be transmuted into food and sustenance, and thus indirectly direct the vital activities of a nation. The scenic grandeur of a great waterfall may be a national asset, but I am one of those who see an even greater grandeur and a more valuable national asset in vast fields of waving grain and contented, well-nourished herds, which mean, as they always have and always will mean, a contented, virile and industrious population."

Relation of Water Power to Transportation

In a paper presented by LEWIS B. STILLWELL the relative importance of water power in its relation to transportation is discussed as depending upon its cost and the cost of competing steam power.

Water Power and Defence

In a paper presented by Dr. WILLIS R. WHITNEY the necessity of home production of nitric acid and nitrates, for farming, industrial and national safety purposes is pointed out.

The United States has no adequate domestic source of fixed nitrogen. Nitric acid is an absolute necessity in the manufacture of any form of explosive as well as in the production of dye stuffs. Ammonia or nitrate compounds are in increasing demand as fertilizers. The present dependence upon Chile is a menace in case of war and involves the payment of export duties and profits amounting to nearly \$5,000,000 annually in times of peace.

Home production is wholly a question of initiative and proper utilization of water power. Failure to establish the industry in the past has been due to economic conditions, such as the relative proximity of Chile and the impossibility of competing with the cheap water powers of Scandinavia as well as the lack of a nearby agricultural demand. The growing need for fertilizers, the desirability of establishing a dye-stuff industry and especially the feeling of uncertainty in international relations make a reconsideration desirable.

National safety demands the development of a nitrogen fixation industry whether it be self-supporting or not. But the industry once established the products would be of the greatest value in times of peace and many other industries would be stimulated thereby. Thorough industrial organization is the best preparedness for either peace or war.

At least two great processes for fixation of nitrogen have been offered to our government in the past few weeks—the arc process of the du Pont Company and the cyanamid process of the Cyanamid Company.

These are both tested processes, and we are interested in their present, and even more particularly in their future developments. In any undertaking by our government which involves the granting of special water power rights, the people should want foresight coupled with active, constructive work. It seems as though we might fairly expect sometimes a change in the public spirit, which now usually views almost any large manufacturing undertaking with animosity and adverse criticism. Possibly through the study of these immediately pressing problems of explosives, dyes and fertilizers by our most competent and interested government experts, sound business criteria may be established for the nation's benefit.

The problem is many sided and far reaching and hence it is very desirable that the various government departments concerned, those of the Army, Navy, Agriculture, and Interior, with their skilled staffs and expert knowledge should cooperate in determining the course to be taken. Immediate action is very important since at least two years will be consumed in getting any process available into operation, after a decision is reached.

The Water Power Situation, Including Its Financial Aspect

Mr. Gano Dunn, in the last paper of the symposium, presented, from the point of view of the engineer, certain aspects of the attitude of capital toward water powers. Actual and threatened laws, popular prejudices and some cases of unprofitable developments in the past have retarded the development of water powers; but there are also physical and natural difficulties which handicap hydroelectric as compared with steam-electric plants, and make it essential that a reasonable profit in promotion be offered in order to induce investment. The bond interest is a very big item in the cost of water power development.

Washington Meeting, American Electrochemical Society

Report of Proceedings and Abstracts of Papers Presented

The twenty-ninth meeting of the American Electrochemical Society was opened on Thursday morning, April 27. The attendance even on the first day was excellent, as many of the members had attended the water-power conference of the American Institute of Electrical Engineers the day before.

President LAWRENCE ADDICKS in his opening remarks referred to the very satisfactory present status of the American Electrochemical Society. The reports of the board and the standing committees were read, and the election of officers for the coming year was announced.

Mr. FRANCIS A. J. FITZGERALD of Niagara Falls, N. Y., is the new president.

Messrs. Schluederberg, Tone and Walker were elected vice-presidents; Messrs. Bancroft, Hering and Roerber managers. Dr. Richards was re-elected secretary and Mr. Salom treasurer. Mr. FitzGerald in accepting the presidency said he appreciated the honor, and quoted from a letter of Faraday to Schoenbein, "I only hope I may prove worthy of it, but will trust to the kindness of the members to think I will try to deserve it."

Dr. Colin G. Fink, chairman of the New York section, extended a cordial invitation to the society to meet in New York City, in connection with the Second Exposition of Chemical Industries in the week of Sept. 25.

In the following technical session the symposium on co-operation in industrial research created quite an animated discussion. Mr. Addicks thought the big research laboratories of this country were evidence of a kind of failure of our universities; great inventions very rarely come from a university. More frankness is needed on both sides. Professor Bancroft protested it was not a university professor's business to be an inventor, and Messrs. FitzGerald, Lidbury, and Professor Richards agreed that the principal object of a university is to produce men fundamentally grounded in the principles of their profession. Dr. Taylor thought that Victoria University of Manchester had adequately co-operated with Niagara Falls by giving it Lidbury.

Prof. W. H. Walker took sharp issue with Professor Bancroft in his statement that "co-operation was out of the question," and agreed with President Addicks that frankness was the keynote to the solution of the difficulty. He considered the following situation: A technical man has complete information regarding the details of his process, but meets its limitations. He has tried many experiments to enlarge his knowledge, but makes no substantial progress. He frankly lays the

whole matter before a university professor who is ignorant of these facts and in turn frankly admits it. But he has a thorough knowledge of the principles of science, and has had some training in applying them. He adds his knowledge of science, and both are benefited. This is co-operation. The individuals progress, the two institutions progress, and so does the nation.

A communicated discussion by Mr. Skinner referred to Great Britain's plan of a central research corporation and expressed the thought that Great Britain's action, forced by necessity, might show us the way. Mr. Lidbury thought there was the danger of degeneration in too much co-operation; the industrial research laboratory should not do the university's work nor should the university do the industrial man's work. Mr. Frary thought co-operation between universities and small manufacturers desirable.

President Carty of the American Institute of Electrical Engineers made a very cordial speech on the desirability of closer relations between electrical engineers and electrochemists. Dr. Cutter referred to the search work carried out by the United Library of the A.I.E.E., A.I.M.E., and A.S.M.E.; it is a sort of co-operation between manufacturer and university through the literature on the subject. Mr. White emphasized the importance of joining technical societies and attending the meetings.

The principal discussion in the Thursday afternoon session was in connection with the symposium on Niagara Falls power and American industries.

Mr. Atwater emphasized the enormous increase in by-product coke-oven capacity of this country and thought that ammonia from this source would adequately solve the nitric acid problem in times of war. Mr. Landis thought that this was not so, since this ammonia was used in times of peace for such purposes from which it could not be withdrawn in time of war (for instance, 40 per cent are used in the refrigerating industry). Dr. Mathews reviewed recent progress in electric steel.

Mr. Lidbury covered in a long address the expatriation of electrochemical industries due to the power famine on the American side of Niagara Falls; these industries are forced to move away to Canada and even to Europe, though their products are destined largely for the American market. There is very grave danger that Canada will withdraw the permits of exportation of power to the American side. Canada realizes its opportunities. Something must be done by the United



PHOTOGRAPH OF AMERICAN ELECTROCHEMICAL SOCIETY AT MOUNT VERNON, VA., ON APRIL 28

States to relieve the power famine at Niagara on the American side. Are we prepared to see these industries which are of such fundamental importance to the American nation emigrate to other countries?

Very interesting and pretty lantern slides were shown by Director A. P. Davis, chief of the Reclamation Service, in an illustrated address on water powers obtained as a by-product in irrigation development work.

The Thursday evening session was devoted to the final paper on water power development, being an illustrated lecture by J. H. PIERCE of Seattle, Wash. In introducing the speaker, Mr. John J. Finney who was presiding, stated that our nation had been led away from an attitude of fairness and sanity on the water power ques-

tion of temperature was adopted. The electroplating papers elicited a great number of questions and answers, many members participating in the discussion.

In the following we give a complete alphabetical list of all who registered up to Friday afternoon:



FRANCIS A. J. FITZGERALD, PRESIDENT
AMERICAN ELECTROCHEMICAL SOCIETY

tion and that we must labor to make the fundamentals of the problem better understood by government authorities. Mr. Pierce's paper was largely statistical, showing the comparative lack of water power development in this country. Out of 6,678,000 potential water horsepower in the United States, only 10 per cent is being utilized. The speaker outlined the uses of hydroelectric power in pumping water for irrigation, railroad transportation and fixation of atmospheric nitrogen. The main reason for the lack of more rapid development of hydroelectric power in this country has been restrictive federal laws which must now be modified if we are to enjoy the possible advantages of our natural resources. Very pretty moving pictures and lantern slides were shown.

In the Friday morning session the papers on the passive state and over-voltage elicited quite an extended and animated discussion of considerable theoretical interest. Particularly interesting were the remarks of Dr. Langmuir, who thought that a new viewpoint was needed; he provided one from his experimental work on gas reactions at low pressures and proposed a new theory of the passive state which reconciles the different older theories.

On Friday afternoon a boat trip was made to Mount Vernon. In the evening session Dr. Cushman presided. In the discussion of Mr. Aston's paper on corrosion as an aid to further corrosion Dr. Cushman emphasized that corrosion is distinctly a problem for electrochemists and not chemists. Further metallurgists must contribute to the solution of the problem in the production of sound metal as the starting point. Mr. Speller emphasized that corrosion is an effect of surface differences and due to surface reactions.

The Saturday session, at the Bureau of Standards, was opened by an address of Director Stratton. Dr. Carl Hering's resolution in favor of the centigrade scale

Paul O. Abbé, New York; Mr. and Mrs. Lawrence Addicks, New York; H. B. C. Allison, Schenectady, N. Y.; G. C. Andrews, New Britain, Conn.; F. L. Antisell, Perth Amboy, N. J.; Mr. and Mrs. William C. Arsen, Schenectady, N. Y.; W. Arthur, Philadelphia; James Aston, Pittsburgh, Pa.; C. G. Atwater, Philadelphia; A. Aupperle, Middletown, Ohio; L. H. Bazeland, Yonkers, N. Y.; Mr. and Mrs. T. F. Bally, Alliance, Ohio; Edward M. Baker, State College, Pa.; A. T. Baldwin, New York; Mr. and Mrs. Wilder D. Bancroft, Ithaca, N. Y.; John S. Bates, Montreal, Canada; E. H. Bedell, Newark, N. J.; Marcus A. Beeman, Washington, D. C.; W. Bennett, Ithaca, N. Y.; E. R. Berry, Malden, Mass.; W. D. Bigelow, Washington, D. C.; E. Blough, Pittsburgh; W. Blum, Washington, D. C.; William H. Bristol, Waterbury, Conn.; de Courcy Browne, New York; A. R. Calder, Harrisburg, Pa.; Frank L. Cameron, Washington, D. C.; J. N. Carothers, Washington, D. C.; S. C. Carrier, New York; W. H. Carrier, Buffalo, N. Y.; Mrs. O. T. Cartwright, Washington, D. C.; John J. Carty, New York; L. W. Chaney, Cleveland, Ohio; N. K. Chaney, Lakewood, Ohio; K. B. Chills, Jr., Cleveland, Ohio; J. K. Clement, Pittsburgh; J. H. Clough, Schenectady, N. Y.; Mrs. G. W. Coggeshall, Washington, D. C.; Mr. and Mrs. H. B. Colo, New York; Mr. and Mrs. E. A. Colby, Newark, N. J.; Mr. and Mrs. G. E. Condra, Lincoln, Neb.; E. F. Coner, New York; William C. Cope, Pittsburgh, Pa.; W. M. Corse, Buffalo, N. Y.; Mr. and Mrs. F. G. Cottrell, Washington, D. C.; James L. Cowie, Washington, D. C.; J. S. Crider, Cleveland; R. A. Crider, Cleveland, Ohio; E. L. Crosby, Detroit, Mich.; T. E. Crossman, New York; Mr. and Mrs. William J. Cummings, Haskell, N. J.; Allerton S. Cushman, Washington, D. C.; Newton E. Babolt, New York; H. T. Darling, Philadelphia, Pa.; A. W. Davison, Cincinnati, Ohio; P. K. Devers, Lynn, Mass.; Bradley Dewey, Pittsburgh, Pa.; F. P. Dewey, Washington, D. C.; Herbert G. Dorsner, Granville, Ohio; C. Drefahl, Cleveland, Ohio; I. R. Edmonds, Niagara Falls, N. Y.; C. Q. Fairchild, Washington, D. C.; E. Felician, Philadelphia, Pa.; Colin G. Fink, East Orange, N. J.; John H. Finney, Washington, D. C.; Mr. and Mrs. F. A. FitzGerald, Niagara Falls, N. Y.; H. Flanagan, New York; P. T. Fletcher, Detroit, Mich.; Charles B. Foley, New York; Francis C. Frary, Niagara Falls, N. Y.; T. S. Fuller, Schenectady, N. Y.; H. A. Gardner, Washington, D. C.; A. E. Gibbs, Philadelphia, Pa.; C. B. Gibson, Pittsburgh; A. McK. Gifford, Pittsfield, Mass.; H. W. Gillet, Ithaca, N. Y.; Mr. and Mrs. S. L. Goodale, Pittsburgh, Pa.; Mr. and Mrs. J. H. Goodwin, Fremont, Ohio; C. McCheyne Gordon, Easton, Pa.; L. H. Greathouse, Washington, D. C.; Mr. and Mrs. Jesse J. Haas, Washington, D. C.; James Otis Handy, Pittsburgh, Pa.; Mr. and Mrs. Joseph W. Harris, Washington, D. C.; Carl Hering, Philadelphia; A. L. Hinkle, Niagara Falls, N. Y.; Carl D. Hocker, New York; George B. Hogaboom, New Britain, Conn.; H. D. Holler, Washington, D. C.; Mr. and Mrs. Rudolf Tommel, Bethlehem, Pa.; A. H. Hooker, Niagara Falls, N. Y.; H. B. Hoyland, Minneapolis, Minn.; Henry Howard, Brookline, Mass.; Mr. and Mrs. W. F. Hubley, East Orange, N. J.; Matthew Hunter, Troy, N. Y.; O. Hutchins, Niagara Falls, N. Y.; L. L. Hutchinson, New York; T. Iggenbach, Bethlehem, Pa.; H. H. Johnson, Baltimore, Md.; Hennen Jennings, Washington, D. C.; Arthur E. Johnson, Washington; C. Powell Karr, Washington, D. C.; H. J. Kennedy, New York; David A. Keys, Toronto, Can.; H. F. Kleinfelt, Cleveland, Ohio; Walter Lang, Niagara Falls, N. Y.; Landis, New York City; C. P. Landreth, Philadelphia, Pa.; Charles W. Lang, New York; Mr. and Mrs. Irving Langmuir, Schenectady, N. Y.; J. N. Lawrence, Annapolis, Md.; I. H. Levin, Newark, N. J.; A. Libby, Niagara Falls, N. Y.; C. F. Linder, Bridgeport, Conn.; E. J. Lister, Schenectady, N. Y.; Anthony F. Lucas, Washington, D. C.; E. McAusland, Washington, D. C.; E. C. McKelvy, Washington, D. C.; Charles P. Madsen, Newark, N. J.; G. H. Mains, Washington, D. C.; Mr. and Mrs. Wallace W. Main, Cleveland, Ohio; W. J. Madsen, Washington, D. C.; Seabury C. Mastick, New York; J. A. Mathews, Syracuse, N. Y.; Mr. and Mrs. F. N. Moerk, Philadelphia; Roy W. Moore, Schenectady, N. Y.; R. W. E. Moore, Pittsburgh; H. J. Morgan, Washington, D. C.; William Roy Mott, Cleveland, Ohio; J. Malcolm Muir, New York; Adrian Nagelvoort, New York; Adolph H. Nietz, Rochester, N. Y.; W. J. O'Brien, Washington, D. C.; William H. Onken, Jr., New York; D. L. Ordway, Cleveland, Ohio; C. A. Orr, Cleveland, Ohio; Y. Oshima, New York; L. C. Ostrander, Col.; Charles J. Ostrander, Washington, D. C.; N. K. B. Patch, Buffalo, N. Y.; H. G. Patten, Washington, D. C.; R. L. Patterson, Niagara Falls, N. Y.; Axel Paulsson, Stockholm, Sweden; Mr. and Mrs. Petinet, New York; Ralph W. Pope, Newark, N. J.; William B. Price, New York; J. E. Pritchard, H. Randall, Baltimore, Md.; Mrs. M. Randall, Baltimore, Md.; F. E. Rasmussen, Baltimore, Md.; G. T. Reich, Niagara Falls, N. Y.; Malcolm N. Rich, Washington, D. C.; Mr. and Mrs. William J. Rich, Washington, D. C.; Joseph W. Richards, Bethlehem, Pa.; E. P. Roeder, New York; G. T. Roush, Elmhurst, Ind.; Mr. and Mrs. G. A. Roush, So. Bethlehem, Pa.; Mr. and Mrs. W. E. Ruder, Schenectady, N. Y.; David B. Rushmore, Schenectady, N. Y.; B. Russell, Washington, D. C.; Mr. and Mrs. Carl G. Schluenderberg, Pittsburgh, Pa.; F. Schoenau, Berlin-Lichterfelde; T. H. Schaeff, Pittsburgh, Pa.; James Schroeder, Washington, D. C.; Frederick F. Schuetz, New York; Miss Matilda E. Senior, Washington, D. C.; George R. Shepard, Niagara Falls, N. Y.; P. W. Shepard, Washington, D. C.; S. Skerfving, Perth Amboy, N. J.; J. B. Sosman, Washington, D. C.; Fin Sparre, Wilmington, Del.; F. N. Speller, Pittsburgh, Pa.; Miss Squire, Washington, D. C.; H. M. St. John, Chicago, Ill.; C. S. Taylor, Washington, D. C.; Hugh S. Taylor, Princeton, N. J.; E. A. Thum, Cincinnati, Ohio; W. J. Tait, Niagara Falls, N. Y.; Chert Townley, New York; P. M. Turner, Jr., Toronto, Ont.; H. S. Turner, Washington, D. C.; J. W. Turrentine, Washington, D. C.; G. D. Van Arsdale, New York; George W. Vinal, Washington, D. C.; G. H. Von Baer, New York; H. S. Walcott, Washington, D. C.; G. H. Walker, Windsor, Ont.; Herman B. Walker, Washington, D. C.; William H. Walker, Boston, Mass.; Robert S. B. Wallace, Dayton, Ohio; R. G. Waltenberg, Washington, D. C.; R. H. White, Niagara Falls, N. Y.; A. M. Williamson, Niagara Falls, N. Y.; C. A. Wilson, East Orange, N. J.; C. Winder, Niagara Falls, N. Y.; Charles Wirt, Philadelphia; J. C. Woodruff, New York; Miss Agnes Yuncok, So. Orange, N. J.; Mr. and Mrs. John A. Yuncok, So. Orange, N. J.

Presidential Address

Delivered before American Electrochemical Society on April 27.

BY LAWRENCE ADDICKS

One of the results of the upheaval in social institutions which is in progress in one form or another throughout almost the entire civilized world, is going to be a changed attitude toward the engineering profession. Engineering—etymologically it means producing, and might to-day be defined as coordinating the forces of nature and properties of matter to the use of mankind—is one of the earliest occupations of man. Indeed much of what we call animal instinct is based upon an appreciation of engineering principles, as when an animal determines the direction of the wind from deciding which side of its damp nose is the colder from evaporation. And when we teach a boy scout to build a fire in the open without using more than two matches, we may call it woodcraft, but it is a first-class laboratory experiment in engineering.

Although it deals with such fundamental principles, engineering has not been recognized as one of the great professions until well within the last century. This was doubtless due to the fact that until a clear understanding of the principles of thermodynamics and of the laws of chemistry existed, no rational development along lines of efficiency and conservation was possible, and the popular attitude was anticipated by Shakespeare when he wrote:

"Let it work;
For 'tis the sport, to have the engineer
Hoist with his own petard."

The wonderful developments in engineering science in the last generation, however, have put its expositors equally on all fours, if you will pardon the expression, with those of any of the other learned professions. Still, while the accomplishments of the engineer are to-day admitted on all sides, he has not taken the position in the active direction of the affairs of mankind, particularly in matters of government, which after all lie at the very root of our social welfare, that these accomplishments warrant.

The chemist appears to suffer from all the disabilities of the engineer to which are added some misfortunes all his own, which doubtless explains the uncomprehending attitude of the general public toward the chemical branch of the engineering profession.

I suppose the average man, upon being put to one of those psychological tests which require an immediate and unreflecting answer to a question suddenly proposed, would state that a chemist was the British name for a drug store. One of the reasons for this is that the chemist works chiefly with raw materials which the public seldom see as such, while the engineer produces telephones and trolleys and bridges and big guns which testify at close range to his usefulness as a citizen. When we come to the electrochemist, I fear he is generally regarded as the unfortunate result of the electrical engineer having got into bad company, and the color line is apt to be drawn so as to keep the engineering blood pure and put all half breeds in the Jim Crow car with the chemists.

Now this is all wrong. The chemist is as good a man as the electrical engineer and the electrochemist or electrochemical engineer, as I should prefer to call him, should be a better man than either, owing to his wider technical horizon, but our congenial disabilities tend to keep us in the background, which is the reason for these few words in a sort of Booker T. Washington style as to the future of our race.

The affairs of government in this world seem to be run alternately by the soldier and the lawyer. After a

war there is a strong demand for soldiers as presidents and other government officials. Then as the glamor wears off and things calm down, the lawyer, who is the original safety-first man, comes out of his hole and with his gift of speech, persuades the people that laws should naturally be made by lawyers and he will just take charge. The first part of this cycle is based upon the peoples' admiration for the men who do things, and the soldier is well reported in the papers, and the second stands firmly upon that first principle of advertising, that if you say a thing often enough you will not only convince everyone else but you will believe it's so yourself.

In business life the situation is similar; the president of the company is almost always a lawyer or a banker while the man who makes the business worth running in the first place is the technical engineer, somewhere downstairs. This is undoubtedly due in part to the fact that, I hardly know whether to say fortunately or unfortunately, most of us have just a touch of that artistic sense which is shown by devotion to a profession for its own sake, that has always made for exploitation by the more worldly minded and has tended to lower standards.

You know what a crafty looking lot the angels of the old masters are—due to the latter finding it convenient to reproduce the features of their patrons.

The great war has brought the engineer suddenly to the front, not only of the fighting line where he shares honors with the doctor and the nurse, but of the whole complex industrial organization back of this gigantic struggle, both of the countries at war and of those neutral nations undergoing a commercial upheaval. In the fighting zone it is called a mechanical and chemical war. At home our preparedness campaign is steadily assuming shape as an organized piece of engineering, carried on by engineers, which is as it should be, and further we have the very welcome sight of the several large engineering societies acting in harmonious co-operation. At the end of the war there will be an immense amount of physical damage to be repaired which will be another great engineering undertaking. The opportunity is here, the events of the last two years having accomplished what would have required at least a generation of peaceful development.

The great question is whether the engineer will rise fully equal to his opportunity. To do this he must first of all lay aside all narrow sectarianism, the technical men in all branches realizing that they are of a common brotherhood. Then he must broaden his interests and not remain satisfied with the purely technical aspects of the problems which present themselves, but study and grasp their larger economic significance. Finally he must not rest content with acting in a merely advisory capacity in the affairs of business but have the self confidence to see his work through from laboratory to factory, from factory to market, at home or abroad, and, if necessary, from market to the economic situation beyond.

To accomplish these ends he should be not only a member, but an active member, of some professional society. Let him belong to as many societies as he chooses, but select the most congenial and make himself in evidence at its meetings. Then collectively he should endeavor to bring the various societies together in joint meetings, committee conferences, etc., whenever possible, so that the profession may not only present a united front to the public, but know its own mind on questions of general interest. Then, when the engineers are in agreement on a technical question affecting public interest, they should let their collective voice be heard. I believe that it is not only permissible but desirable that technical societies take an active part in legislative hear-

ings, and offer suggestions or protests on public questions, provided only that the opinions advanced are really held by a reasonable majority of the membership, that the questions acted upon are reasonably relevant to the subjects covered by the societies' interests, and that a sharp distinction is drawn between matters of public interest and political campaigning.

In short, I submit that one of the first steps toward giving the engineering profession the place in public influence it deserves should be the vitalizing of the great engineering societies as living representative bodies of engineering opinion and the education of the public and the government to look to them for advice on engineering matters.

The Naval Consulting Board is a most encouraging application of this idea and it is to be hoped that this policy will be extended to other departments of the government. Such a co-operation should make it impossible for Congress to be so long in lack of reliable information on which to base an intelligent constructive policy, that this country should be in a period of military anxiety dependent upon a foreign supply of nitrate for explosives with the only nitric acid produced from the atmosphere being that which turns the milk sour in the refrigerator when we have a thunderstorm.

Thursday Morning Meeting

Co-operation in Industrial Research

The first subject on the program, following the presidential address, was a symposium of seven brief papers on co-operation in industrial research. This was followed by a spirited general discussion.

The *professional society's* position in this matter is discussed in two papers by Mr. LAWRENCE ADDICKS and Mr. F. A. LIDBURY respectively.

Mr. Addicks believes that every society should have a "lion's mouth" where brief statements of lines of commercially desirable research could be dropped. The man in practical work should report his interesting odds and ends to the professional society; the society should publish the problems so stated; the head of a university course should consider such lists in mapping out the work to be done under his direction; the results of such work should be offered to the society for publication. In many cases I believe the results would include a better job for the student when he graduated, additional consulting work offered the professor, practical help to the man in the field and an increase in the usefulness of the society.

Mr. Lidbury is doubtful whether the collection and publication of proposed subjects of investigation by a Society would be worth while. "However, as experimental evidence is the most convincing, there is no reason why the collection of suggested subjects for investigation should not be tried, even if the result were only to add to the gaiety of nations."

As to the co-ordination of investigations in different classes of research institutions, Mr. Lidbury believes that a society's success in this line depends entirely upon its success in its own development and in the attractiveness of its meetings. "In this respect the American Electrochemical Society has been most fortunate, and if it is possible for one of these gentlemen (of whom one hears but rarely finds) who are short of a subject on which to exercise their abilities for investigation to attend a meeting of this Society and not find a dozen, he has surely mistaken his vocation."

The *university's* position is discussed in two papers by Dr. WILDER D. BANCROFT and Dr. W. H. WALKER respectively.

Dr. Bancroft points out that electrochemical research

at most colleges must be limited to problems calling for a moderate amount of power and for relatively short runs. We should keep in mind the distinction between the college professor as teacher and as expert. In so far as he is an expert there is no question of co-operation. It is a case of professional services, paid for as such and carrying with it the obligations of secrecy. The work which cannot be done in the college laboratory will be done in the technical laboratory or in the factory. In so far as the college professor is a teacher, it is obligatory on him to publish his results for the benefit of everybody. Under these conditions the possibility of co-operation is very limited and, as a matter of fact, does not occur to any appreciable extent.

"I believe very strongly in the desirability of an exchange of ideas between the teacher and the technical man. I believe that it is of great value to the teacher to be interested in, and to keep in touch with, technical problems. I believe also that it is a very good thing for the technical man to know as much as possible about the theoretical side of his own specialty and of the allied subjects. I don't see any object, however, in ignoring the fact that the primary business of the college chemist is to find out why things go as they do in a given case, whereas the primary business of the technical chemist is to find out what to do in a given case. The two should each supplement the other; but the differences in the problems themselves, the differences in the scale of the problems, and the differences in regard to publication, seem to me to make co-operation out of the question except in special cases. The industries can subsidize the college laboratories; but let us call it that and not co-operation."

Dr. Walker points out that but for the co-operation of Haber and Ostwald, of the University, with the manufacturers of nitric acid, Germany would long since have gone down in defeat.

Co-operation in industrial research must be based upon a realization of the fact that increase in knowledge must go hand in hand with application of knowledge; that the University must maintain an interest in the application of the laws and theories which it discovers and teaches; and finally that the industries must realize that it is their duty to increase and diffuse knowledge as well as to utilize for their own profit that already existent.

The *Government's* position is outlined in a paper by Mr. Dorsey A. Lyon.

One phase of Industrial Research in which the Bureau of Mines is particularly interested is that which has to do with discovering ways and means for recovering metal values from:

- (1) Ores which have heretofore been considered too low grade or too complex to treat by present-day processes.

- (2) Tailings dumps resulting from the treatment of non-ferrous ores by processes which yield only a comparatively low percentage of the total values contained in the ores.

Mr. Lyon outlines the work done by the Bureau of Mines in co-operation with the University of Utah.

The *corporation's* position with respect to co-operation in industrial research is discussed in two papers by Dr. L. H. BAEKELAND and Dr. W. R. WHITNEY respectively.

Dr. Baekeland outlines the difficulties in co-operation from the corporation's standpoint. This has led to the organization by some large corporations of well-equipped research laboratories where they try to solve their own problems, independently of any outside intervention. But this is expensive and it is difficult to find the right man to run it.

In many cases, however, co-operation in research is practical. "For instance, several concerns interested in the same problems might co-operate together for maintaining a joint research laboratory, or for intrusting a specific problem of research to a man or a group of men who possess the necessary qualifications. That such a plan is possible and profitable is best illustrated by the well-organized research laboratory of the National Cannery Association of Washington, at the head of which is Dr. W. D. Bigelow, formerly of the Bureau of Chemistry, and which I believe is a unique institution of the kind in the world. Why could a similar co-operative research laboratory not be organized for the study of problems of electrochemistry?"

Dr. Whitney points out that just as no man liveth unto himself alone, so no scientific research is separable from the rest of knowledge, and for this reason the greatest value of research will be realized where there is the widest range of utility and interest. The researches of a Mendel, buried in a monastery garden, or of a Gibbs, buried in a "Connecticut Transactions," come to light all too tardily. The applications of these two researches, for example, after years of hiding, now influence the laboratories, the factories, and the farms of the world. But one-man laboratories and one-horse publications fail to fulfil the possibilities of their discoveries because of isolation from the fields of need.

A large corporation can better afford to carry on extended research than a small one. . . . "The effect of co-operation is not merely additive, but rises more nearly as the "n"th power, where "n" is the number of co-operators. And so I am led to regret that large corporations have been so frowned upon. Some time we may realize that at least in so far as research is concerned, it were better if all our productive organizations were united, with a single great research laboratory. Then the poorest furnace slag would be quickly tried for farm fertilizer, tested in cements, made into glass, ground into paints, calendered into writing paper, blown into thermal insulation, turned into asbestos, put into dynamite, or injected into medicines. Every electrochemist who, fraternizing with his own fad, listens to a brother chemist riding his particular hobby, hears the call of co-operation. Men and experiences dovetail, and in the words of the dictionary definition, 'Each finds in the other what he in a double sense wants.' . . . "The plans for a Government research laboratory for the Navy naturally led to the question of turning to account in some way the facilities of private, corporate and university laboratories. Here for the first time a proposal of general co-operation in American research seems practicable. Within the organization of a Government laboratory might be one or more official co-operators. His duty would be to familiarize himself with the needs of problems of the country, the facilities of all the possible research laboratories and the idiosyncrasies of the individual in them. He would inform the latter how he might co-operate, would follow his progress and keep him generally informed. Such a Government employee would be more likely to meet liberal co-operation than would a representative of a university, or of any private or corporate interest. This official would become a traveling encyclopedia. Such a procedure in conjunction with the normal work of a governmental defence laboratory might indicate by experiment what the next best step along this line of co-operation should be."

Wireless Telegraph Detectors

A paper by Dr. WILDER D. BANCROFT emphasizes that the essential thing in the action of electrolytic detectors, crystal rectifiers, and coherers is an adsorbed air film.

The coherer, the electrolytic detector and the crystal detector act as they do because an electrical stress decreases the thickness of the adsorbed gas film and therefore decreases the resistance.

The unilateral conductance of the crystal detectors is essential when there is no battery in the local circuit; but it is of no theoretical importance when a battery is used.

The essential difference between the coherer and the crystal detector is that coalescence takes place readily in the first case and not in the second.

It is not necessary that the oxide film of some coherers should be removed by the current, though this may happen.

In the crystal detectors the marked changes in the behavior of adjacent portions of the same crystal face are probably due to localized impurities.

The papers by Captain E. D. ARDERY on hydrogen for military purposes, by Dr. G. ORNSTEIN on liquid chlorine, and Dr. W. M. GROSVENOR on magnesium had been presented before to the New York Section of the American Electrochemical Society and were published in our issues of March 15, page 333, February 15, page 215, and March 1, page 262 respectively.

Thursday Afternoon Session

The afternoon session was opened by the symposium of papers on Niagara Falls power and American industries; these are published in full on pages, 507 to 518 of this issue.

Brittleness of Annealed Copper

In his paper on this subject, Mr. W. E. RUDER, of the Research Laboratory of the General Electric Co., shows that the brittleness of copper developed during heating in the process of manufacture and frequently ascribed to "burning," is in reality a deoxidation. With ordinary commercial copper, serious brittleness begins to appear at 400 deg. C. in dry hydrogen, at 600 deg. C. in wet hydrogen, at about 800 to 850 deg. C. in CO, and at 700 deg. C. in steam. Copper which had previously been deoxidized by the addition of boron remains unaffected at all temperatures in a reducing atmosphere. This brittleness is therefore due to the reduction of the cuprous oxide around the primary copper grains, leaving a spongy mass of little mechanical strength, and not to any direct action of the hydrogen upon the copper itself.

Cobalt for Thermocouples

In his paper on this subject, Professor O. L. KOWALKE, of the University of Wisconsin, emphasizes that cobalt should enjoy an important place among thermo-elements. It is robust, it can be obtained fairly pure, it does not appear to get brittle like nickel, and it gives a high electromotive force. The only drawback at present is its high price.

The following combinations were tested: cobalt vs. nichrome, cobalt vs. "advance", cobalt vs. constantan, cobalt vs. iron, cobalt vs. nickel-iron. Cobalt is the positive terminal against advance and constantan and negative in the other couples. The results of the e.m.f. tests are given in a series of diagrams. The cobalt-constantan couple seems to be particularly satisfactory.

Nickel-Copper-Chromium and Nickel-Copper-Manganese Alloys

The electrical resistances and temperature coefficients of nickel-copper-chromium and of nickel-copper-manganese alloys were the subject of a paper by F. M. SEBAST and G. L. GRAY, of the Rensselaer Polytechnic Institute, Troy, N. Y., the results being given in numerical tables and diagrams.

With respect to copper-nickel-chromium alloys the following conclusions are reached:—

The effect of the addition of pure chromium to pure copper is that the resistivity of copper is only slightly increased. The form of the curve resembles that for a eutectic alloy. This fact indicates that chromium is only very slightly soluble in copper.

The effect of the addition of pure chromium to pure nickel is that the resistivity of nickel is very greatly increased. The form of the curve in this case indicates that nickel is capable of holding chromium in solid solution.

The effect of the addition of pure chromium to alloys of copper and nickel: For any single Cu-Ni alloy the resistivity first rises and then falls off upon the addition of chromium. At a certain chromium concentration a maximum resistivity is attained for each Cu-Ni alloy, and as the concentration of the copper in the alloy increases, this maximum approaches the axis of zero chromium.

The effect of the addition of chromium on the temperature coefficient: In all cases, when the resistivity of an alloy is increased by the addition of chromium, the temperature coefficient is reduced. And when the resistivity is reduced the temperature coefficient is increased.

An alloy of very high resistivity (112 microms per cm. cube) and of negligible temperature coefficient (0.000078) was found. This alloy (15 Cu, 85 Ni, 20 Cr) would appear to have good commercial possibilities.

With respect to copper-nickel-manganese alloys the following conclusions are reached:—

Within the limits covered by the investigation the addition of manganese to the alloy of copper and nickel at any concentration causes an increase in resistivity. The generally accepted conclusion that an increase of resistivity is accompanied by a decrease of temperature coefficient is in general confirmed for the alloys of copper, nickel and manganese. The curves obtained indicate that there is an alloy containing approximately 55 Cu, 45 Ni and 15 Mn, which has a resistivity of about 70 microms per cm. cube, and a temperature coefficient of zero at 20 deg. C. This alloy is a much better resistor than any of those used at the present time for precision apparatus.

The Small Electric Steel Furnace

"Some Faults of the Small Electro-Arc Furnace for Melting and Refining Steel" are discussed by Mr. W. M. KNIGHT, of the Southern California Edison Co., Redondo Beach, Calif., as follows:

The small electric arc furnace is rapidly coming into favor for the production of small, highly-refined steel castings, and its advent is welcomed by both the manufacturers of steel castings and the electric power companies. Without going into the merits of the electric furnace as a competitor of the crucible furnace and open-hearth furnace, regarding the quality of the product or regarding it as a welcome load builder for power companies, I wish to point out some of the handicaps to its universal adoption and successful operation.

The furnaces that are now in operation in several parts of this country, while differing in some respects in their mechanical construction and electrical demands, all refine the steel by the same chemical process, viz., by raising the temperature of the bath to 2500 deg. C. or better, by boiling the metal to eliminate the impurities, and by the introduction of the necessary refining agents to bring it up to the fineness desired.

All small arc furnaces are constructed on certain general mechanical lines, as follows: The furnace consists of a steel shell mounted on trunnions for tilting to discharge the molten metal. This jacket is lined with a highly refractory lining, sufficiently thick to retain the heat; the lining and shell, however, are pierced with port-holes for the purpose of charging the furnace with steel, adding

the refining agents, discharging the refined metal and for inserting the electrodes, and all these port-holes furnish avenues of escape for the heated gases. The electrodes are secured in place by the holders mounted on tilting shell, and the holder raises or lowers the electrode by hand operation, by hydraulic control, or by electric motor control.

In spite of the fact that the electric furnace to-day is turning out small castings of a better quality and at a lower cost than by other processes, nevertheless, the overall efficiency of the best furnaces on the market is far from 100 per cent.

There are three principal sources of loss:

Electrical.—In the improper delivery of the energy to the metal.

Mechanical.—In the improper design of the furnace shell and ports, to exclude cold air and retain the heat.

Chemical.—The improper combinations of refractory materials, that should be inexpensive in first cost, withstand the intense heat long enough to avoid delays through the interruption of the manufacturing process, and not introduce any chemical combination with the metal. Also, there should be found an electrode that will not waste away too rapidly through oxidation, within and without the furnace, as it comes in contact with the air and gases.

Electrical conditions can be improved by supplying the proper current at the proper potential. Mechanical conditions can be improved by re-designing detail portions of the furnace. The chemical conditions can be improved only by exhaustive research and careful study.

Refractories are of two kinds: the heat-resisting lining and the heat-producing electrodes. The heat-resisting linings may be either acid or basic, depending on the degree of heat required for the quality of steel to be turned out. The heat producing refractories may be either carbon or graphite.

Merely to melt down steel scrap and turn out castings of semi-steel and low-grade castings of unknown quality does not require a temperature of 2500 deg. C., and for a furnace for this class of work an acid lining of silica is successfully used. To refine the steel, however, it is necessary to use a basic lining of magnesite, at least where it comes in contact with the bath, or where the heat would be intense enough to melt down the silica and cause it to run down into the bath and combine with the metal bath or slag and the basic lining, thereby changing their character.

The furnace linings can be put in in two ways: build up with brick work, the bricks made to conform to the shape of the shell and laid up in a basic paste or coal tar binder, or the material for the lining may be made up into a mass and rammed into the shell. The brick lining offers some advantages, inasmuch as it has passed through a glazing process that should prolong its heat-resisting qualities, but it is expensive, particularly if special sizes and shapes are desired, and if the source of supply is remote, and the delivery uncertain.

The rammed lining should be superior from the fact that it is, if properly put in, a monolithic mass, hence there should be little danger of the bath breaking through to the shell, with the resulting damage to the furnace and loss of the bath.

Electrodes are of two kinds: carbon and graphite. Each has its merits. The carbon electrode is the less costly, but has less electrical carrying capacity than graphite, and consequently must be greater in cross-section to deliver the same amount of energy. It therefore has a larger amount of radiating surface, and consequently the saving in first cost of the carbon is offset by the loss in energy dissipated in heat. Owing to the intense heat of the electrode, its surface both within and without the furnace shell loses carbon by its surface contact with the air and resulting oxidation.

The graphite electrode, by virtue of its greater carrying capacity, is smaller in diameter, and offers less surface for radiation of heat and oxidation. The electrode within the furnace shell is subject to further attack by the passage of the electric current through the heated gases to the lining, which, at a temperature of 2500 deg. C., itself becomes a very good conductor of electricity.

Electric steel castings may not be better in quality than those turned out by skilled operators with fuel furnaces, but small electric steel castings can be made at a less cost under present conditions, which conditions could be improved, and then the furnaces will be limited only by the capacity of the source of the supply of electrical energy.

The field has apparently no limitations, if the chemist can overcome the losses I have pointed out. Formulate a better refractory lining, an electrode that will not waste

away except in heating the bath, and utilize the waste gases by manufacturing them into a by-product or by-products.

I have only touched on one single product which gives promise of so much for the electric furnace. The field is undeveloped and has almost unlimited possibilities. In three Pacific Coast States alone, I am informed, there is approximately 1,000,000 hp. in water-power going to waste, because a too zealous government is retarding its development, by capital ready and willing to invest, if more liberal terms of lease can be secured. Such terms might be forthcoming if the American Electrochemical Society would bend its energies to make efficient power consuming devices.

This certainly is the day for the chemist, and his greatest achievements will be in the electrochemical field.

Electric Arc Furnace

The Rennerfelt electric arc furnace is the subject of a paper by Mr. C. H. VOM BAUR. The Stassano furnace was the forerunner of the Rennerfelt. The former started with a radiating arc, playing almost horizontally over the bath, whereas the latter furnace forces the naturally large arc flame violently down on the charge and away from the roof by employing a different method of electrode arrangement. Polyphase current of any frequency and voltage is used.

The advantage of a solid bottom has long been recognized, and the extensive use (33 in operation and 20 building) which this furnace has been put to in less than four years, is largely due to this feature in conjunction with the first-mentioned characteristic.

A full illustrated description of the Rennerfelt furnace was already given in our issue of Oct. 1, 1915 (Vol. XIII, page 702).

The so-called efficiency of electric furnaces depends on the rate at which the heat is forced into the furnace, besides upon good insulation, proper painting, etc. The main point of these is the rate at which the power is consumed. Three or four years ago, 200 kw. was considered ample for a one-ton furnace; now 350 to 375 for this size is common practice. Consequently the melting time has decreased and the kw. hours per ton are less, the cost of the steel in the ladle is less, and the output is correspondingly increased. The practical limit to this high-powering of furnaces is the power of the refractories to withstand the higher heat for sustained periods, the refractories are also subjected to greater differences of temperature between heats, especially with those furnaces where the electric current cannot be maintained while there is no charge in the furnace.

With low-powered Rennerfelt furnaces the power consumption when treating various metals has been as follows:

Melting red brass.....	168 kw.h.per metric ton
“ pure copper	197 “ “ “ “
“ white iron	290 “ “ “ “
“ gray iron	325 “ “ “ “
“ 80% ferro-manganese. 441 “ “ “ “	
“ steel scrap, not ready to pour	455 “ “ “ “
“ and “killing” steel scrap on an acid bottom, about	600 “ “ “ “
“ and refining steel scrap on a basic bottom, about	700 “ “ “ “
“ 80% ferro-manganese and holding, tapping and charging.....	741 “ “ “ “
Making 67% ferro-tungsten, small scale.....	5,730 “ “ “ “

Friday Morning Meeting

The Passive State of Metals

“The Passive State of Metals” is the subject of an extended paper by Dr. C. W. BENNETT and W. S. BURNHAM, in which the general field of passivity, especially that of iron and chromium, is reviewed and reference to previous work is appended. The chief conclusions are as follows:

The passive state of metals is really a slowly dissolving state.

Some metals, chromium, magnesium and manganese, for instance, dissolve as anode when passive with a higher valence than when active.

The different behavior of chromium and iron (representing the two types of action) as anode cannot be explained on theories heretofore put forward. All these theories are objectionable.

Oxidizing conditions develop passivity. Reducing conditions develop activity.

In alkaline solutions, passivity is many times accompanied by a visible film over the surface of the anode.

There are no facts which would support the view that passivity is due to one cause in alkaline, and another cause in acid solutions.

In all cases passivity is due to oxidation.

Oxidations in the sense of (1) increasing the valence, (2) removing hydrogen, or (3) of adding oxygen as a film, are shown to be untenable.

The formation of an oxide as the result of oxidation is arrived at by elimination. This oxide forms a film over the metal by being adsorbed by it. This film protects the metal, and gives its properties to the metal surface. This oxide is unstable in most cases, but is stabilized by adsorption by the metal. The oxide in the case of iron is higher than known oxides, but not so with chromium.

The nobility of the surface, the gradual change of electromotive force, and the instability at elevated temperatures are satisfactorily explained by this hypothesis.

The quantity of oxide required to protect the surface is very small.

In the further oxidation of chromium as anode the higher oxide, CrO_3 , is formed and chromium dissolves as hexavalent ion, since this oxide is soluble. Iron does not dissolve because any higher oxide which may be formed is not soluble readily. The quantity of iron that dissolves is due to the straight solution and decomposition of the higher oxide. This is not quantitative according to any reasonable valence.

The oxide in the case of chromium is not higher than CrO_3 , and is probably CrCrO_3 or CrO_2 .

That in the case of iron is not higher than FeO_2 , and may possibly be FeO_3 , similar to chromium.

Passivity of lead has been shown where there was no visible film. The action here is similar to lead where there is a visible film of oxide.

Passivity in all cases, therefore, is the coating of the metal, by adsorption, with a film of a higher oxide which, being more noble than the metal, protects it from the action of the solution. We measure the electromotive force of the oxide instead of the metal. According to this view all the facts of passivity are easily explained, and many conflicting experiments are brought into line with facts.

Overvoltage

The paper by Dr. C. W. BENNETT and J. G. THOMPSON on overvoltage first points out that any chemical reaction, consisting of more than one step, in generating electricity cannot be strictly reversible, but requires more electrical energy to reform the substances than is

given by the reverse reaction. This irreversibility gives rise to over or excess voltage, since the quantity factor is constant.

A general definition of overvoltage is given by the authors and a general and more elaborate theory of overvoltage is developed. This theory is that the excess of the back electromotive force of the system during electrolysis over the reversible electromotive force of the system consisting of the final products is due to the accumulation during such electrolysis, of unstable intermediate products above the equilibrium concentration.

These products are unquestionably active hydrogen, H_2 , active oxygen, O_2 , etc., in case of gases, and metallic metal analogous to vaporized metal in the case of metal overvoltages.

These products are more reactive than the final products and are sufficiently active to explain overvoltages found experimentally.

Active hydrogen is capable of reducing cadmium from cadmium sulphate solutions, and reducing zinc from zinc oxide.

The theory put forward satisfactorily explains the known facts of overvoltage, a condition not satisfactorily met by previous theories.

Overvoltage and Monatomic Hydrogen

In his paper on this subject, Prof. WILDER D. BANCROFT of Cornell University shows that the theory of the irreversible electrolytic decomposition of water gives us a very plausible explanation for some of the peculiarities of sodium amalgam, chromous chloride, and zinc dust. The normal relation between high overvoltage and high reducing power or oxidizing power may be obscured or made to disappear entirely in case of special adsorption of the reacting substance by the electrode, in case of a specific catalytic action of the electrode on the reaction, or in case of a catalytic action of the dissolved substance on the reaction, $2H \rightarrow H_2$, either directly or indirectly, by affecting the electrode catalysis. The assumption of monatomic hydrogen as intermediate product at the cathode has proved useful as a working hypothesis. While we now consider nascent hydrogen as consisting in part of electrically neutral monatomic hydrogen; we recognize that the percentage of monatomic hydrogen may vary enormously and that nascent hydrogen from one source is not necessarily equivalent to nascent hydrogen from another source.

Depolarization by Electric Waves

In his paper on this subject, Prof. WILDER D. BANCROFT shows that electrical waves must cause depolarization if we admit that electrical stress cuts down the adsorption of a gas by a solid. This assumption is a necessary consequence of Schuster's work on disruptive discharges and accounts for the behavior of fountains, impinging jets, rolling drops, and soap bubbles, when electrified slightly. Electrical waves do decrease overvoltage at the cathode and at the anode, and the assumption accounts for all the facts so far known. It is also pointed out that measurements of decomposition voltage involving the use of an intermittent direct current are subject to an error which is perhaps not negligible.

Electrode Surface Phenomena

In his paper on this subject, Mr. WILLIAM C. ARSEMAN of the Research Laboratory of the General Electric Company refers to a theory developed by him on the mode of union of atoms to form molecules and applied to the explanation of various phenomena, among which were the formation of ions, and the behavior of electrolytes on the passage of a current.

The theory states that if an atom be considered to be a system of electrons, a molecule is a union of two or more systems in such a manner that one or more electrons is common to each pair of adjoining atoms. If only one electron is shared by two atoms, the union between them is monovalent and can be represented by a single bond. If two electrons are shared, the union is bivalent, and so on. If a molecule is separated at any union in such a way that the shared electrons are divided unequally between the two portions, these portions become ions with electric charges.

It will be seen that a positive ion by gaining an electron would become reversed in sign and be changed into a negative ion, and *vice versa*. The possibility of this reversal seems to me to afford a way of explaining some electrode phenomena.

Let us consider an electrode in solution, with a voltage applied between two electrodes, and give our attention to the cathode. Here we have a stream of positive ions approaching the cathode, and in the cathode itself a supply of electrons tending to escape into the solution. Every positive ion that reaches the cathode or its immediate vicinity will acquire an electron and become reversed in sign, then as a negative ion it will start on a return journey toward the anode. Before long, however, it will begin to collide with positive ions approaching the cathode, and eventually one of these collisions will result in union to form a neutral molecule. At a small distance from the cathode there will be a zone where neutral molecules are being formed by collision of ions. We may call this the "neutralization zone" or "collision zone."

Taking, as a concrete case, a cell containing hydrochloric acid being electrolyzed with insoluble electrodes, we would have on the cathode a layer of *negative* hydrogen ions and at some distance away a zone of combination where molecular hydrogen is being formed; and at the anode a layer of *positive* chlorine ions with a corresponding zone of formation of molecular chlorine.

The neutralization zone at the cathode would consist of a saturated water solution of hydrogen but no chlorine or hydrochloric acid. At the anode, if chlorine were the only product of electrolysis we should have in the neutralization zone a saturated solution of chlorine. It is in the neutralization zone that neutral molecules are formed from the ions and afterward deposited on the electrodes. The molecules when first formed are separate or dispersed, that is, they are in the form of a solution.

The neutralization zone, then, is a very thin space close to the electrode surface containing pure solvent, dissolved neutral molecules, and any non-electrolyte which may be present.

As soon as e.m.f. is applied to a simple cell of this kind, the neutralization zone with its two charge layers of ions begins to form. If the e.m.f. is not too high, a condition of equilibrium is soon reached in which the neutralization zone has a definite thickness and is saturated with the ionic reaction product in molecular form, but contains no ions.

If the e.m.f. is raised above the decomposition point, there is a leakage of ions across the zone, and a further formation of neutral molecules, which are at once liberated, since the solution in the zone is already saturated with them. Under these conditions, then, a continuous formation of a molecular product takes place. If the molecular product is normally a gas it collects into bubbles and escapes, leaving enough behind to saturate the solution. If the molecular product is a solid it may condense and deposit on the electrode as a coherent coating, or it may form fine particles which deposit as a spongy coating or remain disseminated in the liquid, producing in the latter case a "metal fog," such as is sometimes observed in the electrolysis of fused salts.

A solid formed by an ionic reaction in the neutralization zone may be considered as separating from a saturated water solution. It would therefore be expected in some cases to show crystalline properties. Metallic deposits are generally crystalline, and are to be considered as having crystallized out of the solution in the cathodic neutralization zone. The effect of a colloid in the electrolyte would be explained according to this theory as due to interference with crystallization from the water solution, since the colloid would be present in the neutralization zone as well as in the rest of the electrolyte, because it is undissociated.

In cases where the electrode sends ions of its own material into the electrolyte, the product of the ionic reaction in the neutralization zone between the positive ions from the anode and the anions of the electrolyte may be a substance having special properties. When aluminum is used as an anode in some solutions, a very tough film of alumina is formed in the neutralization zone, which under certain conditions of temperature and voltage has been found to be crystalline.

The paper further deals with the capacity effect, over-voltage and the nascent state.

Contact Resistance of Metal Electrodes

In his paper on this subject, Mr. N. K. CHANEY of the National Carbon Company, Cleveland, Ohio, refers to the high "contact resistance" which, under certain conditions, exists between the surface of an electrode of sheet zinc and the electrolyte.

This "contact resistance" between zinc and an electrolyte of zinc chloride and ammonium chloride is a secondary development occurring with measurable rapidity after the immersion of the zinc in the electrolyte. At the instant of immersion it is very small. It may rise to values of from 200 to 400 ohms per square inch (1250 to 2500 per square centimeter) of electrode surface.

It forms the principal part of the internal resistance of dry cells at low current drains, and as determined by measurements upon the latter it has a high temperature coefficient, decreasing to one-tenth of its value with a temperature rise of from 0 deg. to 45 deg. C. It is this contact resistance of the zinc electrode which was measured by Carhardt in his resistance measurements upon the early Gassner dry cells, and which caused the rapid rise in his resistance curves at low current densities.

It is lessened or destroyed temporarily by current densities above certain low limiting values, being practically unaffected by currents of less than 1 milliampere per 50 sq. in. (315 sq. cm.) of electrode surface, even if continued for a considerable time. With higher current densities it begins to decrease rapidly, and becomes negligible at current densities of about 1 amp. per 50 sq. in. (315 sq. cm.). Upon open circuit the resistance again slowly rises toward its initial value.

It is destroyed or very greatly reduced by chemical treatment of the zinc surface, *e.g.*, by corrosion with dilute sulphuric acid.

An explanation of the high contact resistance observed between the zinc electrode and the electrolyte is based upon the supposed existence of a hydrogen film upon the electrode surface, discharged there by local action between the zinc and the electrolyte. This is supported by a considerable amount of experimental evidence, in which it is shown that the predicted behavior of such a hydrogen film under selected conditions is in agreement with the observed behavior of the contact resistance.

These facts must have a significant relation to the theories of over-voltage phenomena and kindred problems bearing on the nature of the equilibria between the electrode surfaces and the electrolyte.

Relation Between Contact Potentials and Electrochemical Action

A very elaborate and interesting paper by Mr. IRVING LANGMUIR, of the Research Laboratory, General Electric Company, is summed up by the author as follows:

The history of electrochemistry has been marked by a century-long conflict between the contact theory and the chemical theory of electrochemical action. The modern electrochemist usually considers that this conflict has long been brought to a close by the victory of the chemical theory. He believes that contact potentials between metals are entirely inappreciable. No such uniformity of opinion has existed among physicists.

Within the last few years very remarkable work in physics has demonstrated that contact potentials of large magnitude do exist, even between pure metals in a practically perfect vacuum. This evidence, which is

reviewed in some detail, has been obtained by the study of 1, Electron emission from heated metals; 2, Photoelectric phenomena; 3, Contact potentials. Several independent methods lead to values of the contact potentials which are in substantial agreement.

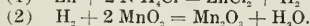
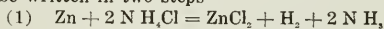
Much of the difficulty which the electrochemist has had in reconciling the contact theory with the known intimate relation between chemical action and electrochemical phenomena, has been due to failure to properly define "potential difference" and "electromotive force." Definitions of these are given, and a theory of the mechanism of the effect is developed.

It is not necessary to take into account contact potentials when only the electromotive forces of reversible cells are considered. But in dealing with the kinetic phenomena, such as over-voltage and passivity, or with effects due to single potential differences, the contact potentials must be an essential factor.

Friday Night Session

Polarization in Leclanche Cells

In his paper on this subject Dr. DUNCAN A. MAC-INNES refers to the reaction of the Leclanche cell, which may be written in two steps



Thompson and Crocker in discussing the cause of polarization in this cell have reached the conclusion that accumulation of ammonia is the cause. The present author, on the other hand, thinks that the formation of free ammonia is insufficient to account for polarization of the order of half a volt or more and gives reasons in support of his view.

It is probable that upon taking current from a cell the reaction represented by equation 1 will proceed more rapidly than that of equation 2, and that the hydrogen pressure will rise above the equilibrium value.

There is also the possibility, suggested by Allmand, that the current is carried from the electrolyte not by the discharge of hydrogen ions, but by the direct change of valence of the manganese compounds. Whether this latter reaction or reaction 1 takes place depends on the relative velocities of these reactions.

Electrolytic Formation of Perchlorate

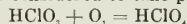
The paper by Dr. C. W. BENNETT and E. L. MACK on electrolytic formation of perchlorate reaches the following conclusions:

Chlorate may be oxidized to perchlorate by persulphuric acid, ozone, and hydrogen peroxide in acid solutions.

In the case of hydrogen peroxide the hydrochloric acid formed interferes with the reaction.

This oxidation may also be carried on with oxygen activated by ultra-violet light.

The reaction is considered to take place according to:



the quantity of oxidation depending on the concentration of active oxygen present.

Since active oxygen chemically produced oxidizes chloric acid to perchloric acid and since active oxygen is formed at the anode it follows that the electrochemical formation of perchlorate is the result of direct oxidation.

Perchlorate is formed at the anode at a potential, far below that necessary for the continuous discharge of any ion present in the solution.

The conditions realized in the experiments described above duplicate, qualitatively, those existing at the anode during electrolysis.

The papers by Dr. W. G. CADY on unstable states in

arc and glow, Mr. W. A. DARRAH on electric arcs in vapors and gases, Mr. W. MCF. MOORE on the Moore tube for color matching, and Dr. W. H. WALKER on corrosion and the engineer had already been presented before the New York section of the Society and were published in our issue of Nov. 15, 1915, page 866, Dec. 1, 1915, pages 915 and 885, and April 1, 1916, page 388, respectively.

Effect of Rust Upon the Corrosion of Iron and Steel

The paper by Mr. JAMES ASTON, of the Bureau of Mines, emphasizes one factor that has not received the attention which seems warranted, that is the influence of rust once formed upon the progression of rusting. Whether we fall back upon the acid or electrolytic theory to account for the inception of rust, we grant that it will form; for formation under the most unfavorable conditions is what each faction claims to prove. Once formed, what part does it play in subsequent reactions? As a result of much observation and study of the characteristics of rust, the following conclusions are advanced:

(1) Rust plays a rôle in the electrochemical relations at least equal to that of constituents usually assumed to be highly detrimental.

(2) Very probably in all cases, but almost certainly when rust is freshly formed, its influence is not as an electrode, but as a coating which affects the polarity of the underlying iron.

(3) Rust plays a dual rôle; the underlying iron may be anodic or cathodic to bare iron, depending upon the state of hydration. But fresh wet rust makes this iron electropositive.

(4) Rust is an accelerator of further rusting.

These four points are discussed by the author in some detail.

The paper by Dr. B. MCCOLLUM and G. H. AHLBORN, on the influence of frequency of current on electrolytic corrosion, had been already presented before the New York section of the Society and was abstracted in our issue of April 1, 1916, page 389.

Saturday Meeting

The program of the Saturday meeting, at the Bureau of Standards, comprised the papers on electrolytic refining and electroplating.

The paper by W. R. INGALLS on Electrolytic Zinc had been presented before the New York section of the Society and was published, practically in full, on page 264 of our issue of March 1.

The paper by OLIVER W. STOREY, of the C. F. Burgess Laboratories of Madison, Wis., entitled Review of Recent Progress in Electrolytic Iron, is published in full on pages 534 to 536 of this issue.

Electroplating Papers

Mr. GEORGE B. HOGABOOM in his paper on Some Unsolved Problems of the Electroplater, emphasized the need of whole-hearted co-operation between electroplaters and electrochemists. The evolution of electroplating solutions has been in three periods: the complicated, the extremely simple, and the efficient solution. The day of the complicated solution has passed, as it was not efficient; the simple solution lacked some of the good qualities of the complicated one, and now the electroplater enters into the third stage and his quest is for an efficient electroplating bath.

The author gave a catalog of some unsolved problems of the electroplater as follows:

1. To what extent is the nature of the electrodeposited influenced by the physical structure of the metallic base, such as steel, copper, brass, Britannia, German silver, etc.? (It has been proven beyond doubt that the character of the deposit is materially affected by the structure of the metal

receiving the deposit; especially is this true of steel and German silver).

2. What is the best cleansing process to use on buffed German silver flatware, to produce 100 per cent perfect plating?

3. *Ditto* on steel and hollow-handle table cutlery?

4. What is the best method of obtaining a smooth adherent silver deposit upon perfectly cleansed German silver flatware?

(a) By placing directly in silver strike?

(b) By use of mercury dip followed by silver strike?

(c) Striking in nickel bath followed by silver strike?

5. What is the best method of obtaining smooth, adherent silver deposit upon steel and hollow-handle table cutlery? Is it best to strike the silver on direct, or place in nickel bath and strike with silver afterward?

6. What composition of silver bath will produce the most efficient deposit, *viz.*, most smooth and rapid, upon German silver flatware, hollow ware, deposit work, table cutlery?

What is the highest current density that can be used in this bath to obtain smooth deposits at 65 deg. Fahr. (18 deg. C.) and what agitation is best?

7. What simple, rapid and convenient method is there for determining the amount of nickel and free acid in the nickel bath?

8. What simple method is there for determining the cause of nickel solutions working dark or otherwise unsatisfactory? What is the remedy?

9. How can the rusting of silver-plated cutlery, while in use, be prevented?

10. What causes silverware to "spot out" before it reaches the consumer? Also brass, copper, and bronze-plated objects? (Pitting of nickel deposits is another problem. It may be caused and very probably is caused by the adherence of gas bubbles and has, in a measure, been prevented by agitating the solution with air or keeping the cathode in motion. If a bath is agitated, however, the sludge will cause rough deposits and unless pure nickel anodes are used iron with which nickel anodes are alloyed, will be deposited with the nickel).

11. How can nickel deposits be made to adhere firmly to tin or tinned articles? (There is no difficulty in depositing nickel upon tin so that it will stand buffing, but if the deposit becomes broken it can be peeled off in strips very easily. The condition is true of imported nickel-plated tinware as well as domestic).

12. What are the factors controlling the hardness or stiffness of copper deposit? It is well known that this is dependent upon the rate of deposit, amount of free acid in the bath, temperature, impurities, etc. Why is the deposit hard or soft? The hardness is not essentially accompanied by either fine- or coarse-grained deposits. The problem is to get a hard deposit independently of the rate of deposit and at will.

13. A practical solution for the deposition of chromium is greatly desired. Chromium deposits are less susceptible to the action of the air and moisture than nickel and therefore tarnish less easily.

14. A positive rust-proof coating, black in color, for iron and steel, without the use of excessive heat.

15. A dip to produce a brass coating on iron and steel by simple immersion, similar to a copper dip.

16. Why will a single nickel salt solution plate zebra-like black and white streaks when the work is given a mechanical motion during the deposition while it plates very satisfactory, white and smooth, when used as a "still" solution?

17. A substitute for platinum chloride to produce the same color effect upon silver. Platinum black is the only durable and satisfactory color for "oxidized" and "French gray" finishes at the present time.

18. Arsenious acid added to a cyanide brass solution brightens the deposit. It also materially decreases the efficiency of the bath. It is well known that the presence of arsenic in copper wire injures its conductivity. Does it affect the deposition of copper from a brass solution in the same manner?

19. If a cyanide copper solution is made from an alkali cyanide, cyanide of copper and a small amount of soda ash, the anode efficiency cannot be maintained at 100 per cent unless the free cyanide content is kept at such a point that a slight decrease in the metal content will cause blistering of the deposit. What salt can be added that will corrode the anode, producing a compound that will be easily soluble in the free cyanide, and thereby keep the anode clear? Bisulphate of soda is recommended by Roseleur, Langbein, Barlay and Hainsworth and other writers on electroplating. That salt decomposes the free cyanide and decreases the cathode efficiency. Large amounts will result in only a slight film of copper being deposited. Watts recommends bi-tartrate of potassium, which is very ex-

pensive and would increase the cost of production. Miller advises aqua ammonia, the effect of which is soon lost in a hot solution.

20. A successful cyanide of zinc solution, one in which there would be a fairly good anode corrosion so that the bath could be kept uniform in metal content.

21. A plating rack or a covering for one that would not be coated with metal except at the points of contact with the articles to be electro-plated. Tons upon tons of metal are deposited upon racks every year which must be refined at a heavy expense or be sold as scrap metal.

22. A satisfactory solution for the deposition of a true bronze, i.e., copper and tin. Fields recommends a double ammonium oxalate solution. In experimenting with this solution Mathers found that at "first such a bath gives a rough copper, then a bright copper and then a bronze which gradually becomes whiter until it is as white as tin." He was unable to maintain conditions required for a rich uniform bronze.

23. A brass solution from which the metal can be deposited as efficiently as copper can be from an alkali cyanide bath and not be coarse or brittle. One in which the anode efficiency will approximate 100 per cent without the addition of large amounts of aqua ammonia or any ammonium salts which either quickly decompose or decrease the cathode efficiency.

24. What is the comparative value of cyanide of potassium and cyanide of sodium in relation to the corrosion of the anode, solubility of the compound formed at the anode, and conductivity, in the commercial electro-plating solutions generally used?

NICKEL PLATING

A paper by Professor F. C. MATHERS, E. H. STUART and E. G. STURDEVANT on nickel plating gives an account of an extended research, the chief results of which are as follows:

The purest nickel anodes obtainable should be used. Strips of electrolytic nickel cathodes, 98.3 per cent pure, used directly as anodes, dissolve irregularly and with pitting, but no impurities are introduced into the bath. Very much of the trouble with badly colored deposits and with sludge is caused by the iron from impure anodes.

The addition of 2 per cent of magnesium or nickel chloride makes the anode corrosion approximately theoretical.

The nickel anodes, supported by lead hooks, may be completely immersed in the solution, thereby greatly reducing the amount of scrap metal from the anodes.

The anodes should be placed in bags in order to catch loosened particles which cause pitting if they reach the cathode.

The addition of 0.2 to 0.3 per cent of ammonium citrate keeps the solution clear and free from sludge, whereby a more shallow tank and a less volume of solution may be used.

The bath should be stirred or mixed thoroughly at intervals but not within 8 to 10 hours of the time of using if any solid particles from the anodes are present.

The greater the ratio of nickel sulphate to nickel ammonium sulphate the brighter and more shiny the deposit. The more acid the solution (to the point of acidity to Congo red) the more shiny the deposits.

Boric acid increases the current that can be used without blackening or burning the deposit.

The following bath seemed to be the best: nickel ammonium sulphate 4 per cent, nickel sulphate 10 to 14 per cent, boric acid 1 to 3 per cent, magnesium chloride 2 per cent and ammonium citrate 0.2 to 0.3 per cent.

A current density of 1.6 amp. per square decimeter (14.8 amp. per square feet) which plates a thickness of 0.0025 cm. (0.001 in.) in 1.25 hours may be used.

The paper by Dr. OLIVER P. WATTS, of the Laboratory of Applied Electrochemistry of the University of Wisconsin, on Rapid Nickel Plating, contains a very interesting discussion of the progress made in increasing

the speed of nickel plating and sums up the advantages of a hot over a cold nickel solution as follows:

Heating from 25 deg. to 70 deg. C. (79 deg. to 158 deg. Fahr.) lessens the resistance of the solution one-half.

The current density may be increased two and a half to three fold.

The current efficiency, if less than 100 per cent in the cold solution, is raised.

Anode corrosion is greatly improved, and higher current densities may be used at the anode as well as at the cathode.

The deposit is superior to ordinary nickel plate in toughness and freedom from peeling.

In the solution tested, plating may be done at 200 to 300 amperes per square foot (22 to 33 per sq. dm.), at which rate the same amount of metal is deposited in five minutes as requires one and a half hours in the "rapid solutions" now in use at 10 amp. per square foot.

TIN PLATING

The paper by Prof. FRANK C. MATHERS and BARRETT W. COCKRUM, of Indiana University, Bloomington, Ind., on Tests of Tin Plating Baths gives an account of many tests of various baths proposed. The results were disappointing. The stannous ammonium oxalate bath containing peptone as an addition agent (U. S. P. 921,943; Met. Chem. Eng., 7, 285 (1909).) gave a smooth, firm, finely-crystalline deposit, the best obtained from any bath.

A second and far more optimistic paper by the same authors emphasizes the use of Peptone as an Addition Agent in Stannous Ammonium Oxalate Baths. The conclusions are as follows:

The addition of peptone to the stannous ammonium oxalate bath is essential for the production of a thick, smooth, finely crystalline deposit of tin. No other tin bath (except possibly the sulphide, which was not tried) is known from which such a thick, smooth deposit can be obtained.

A good composition of bath is: 5 per cent stannous oxalate, 6 per cent ammonium oxalate, 1.5 per cent oxalic acid and 0.25 per cent peptone. The stannous oxalate may be easily made by precipitating a solution of stannous chloride with oxalic acid.

The bath was run at room temperature at 0.4 amp. per sq. dec. (3.6 per sq. ft.). The solution must be stirred at intervals.

SILVER PLATING

Prof. FRANK C. MATHERS and JOHN R. KUEBLER, in their paper on addition agents in the electrodeposition of silver from silver nitrate solutions, state that in their experiments with the ordinary addition agents such as glue, peptone, clove oil, aloin, etc., these were found to be either without appreciable effect or to prevent only partially the formation of crystals and in no case was a thick, smooth deposit obtained.

Tartaric acid was far superior to anything else that was tested.

The following summary of the results is given by the authors:

Tartaric acid is the most effective substance for producing solid, firm deposits of silver from the ordinary silver refining bath containing silver nitrate and nitric acid. A good composition of the bath is 3 per cent each of silver as silver nitrate, nitric acid and tartaric acid. The further addition of 0.01 per cent of glue twice daily makes the deposit much smoother and of a darker, more shiny color.

The addition of 2 per cent ferric nitrate to the above baths makes the deposits much smoother, darker

and more shiny. Analysis of a cathode showed 0.086 per cent of iron.

If economy in addition agents is desirable at the sacrifice of some smoothness in the deposit, 0.5 per cent tartaric acid and 0.01 per cent of glue twice daily can be used. More tartaric acid must be added after about 100 grams of silver have been deposited from each 100 cc. of solution, otherwise loosely adhering crystals are formed.

A current density of 22.4 amp. per sq. ft. (2.45 amp. per sq. dec.) in a vigorously stirred bath gave a firm, smooth deposit which was a little heavy on the edges. A current of 35 amp. per sq. ft. (3.8 per sq. dec.) gave a firm deposit with still rougher edges. In a bath only gently mixed or stirred, 7.4 amp. per sq. ft. (0.8 amp. per sq. dec.) gave the best results. With 6 per cent silver solutions, 14.8 amp. per sq. ft. (1.6 per sq. dec.) could be employed.

The ordinary addition agents as glue and peptone, by themselves, only partly restrained the crystalline structure and did not produce smooth deposits.

Metaphosphoric acid caused the deposit to be hard and non-crystalline, but the bath soon deteriorated.

The weight of tartaric acid used up is 0.005 of the weight of silver refined. The maximum cost of the tartaric acid and the glue at present prices is 0.23 cent per pound of refined silver.

The deposit is brittle, hence it is of no value in plating.

Concentration by Flotation

In a paper presented by F. G. FUCHS at the recent Pan-American Scientific Congress the author deals mainly with experiments to determine to what extent the phenomena of concentration by flotation are due or can be related to capillarity. To this end, he ascertained the adhesive action of oil on different minerals. He found that some minerals, among them quartz, limestone, manganese-siderite, and alabaster, were not wetted by oil, while others, mainly galena and chalcocite, were strongly wetted, it being almost impossible to remove the adhered oil even by vigorous rubbing with a cloth. In his principal experiments he used a glass beaker nearly full of water, on the surface of which he poured oil to form a 5-mm. layer. He then placed on the surface small fragments of the various minerals. The results were: (1) some minerals, especially quartz, fell through the oil layer to the bottom, carrying with them some oil, which, however, soon detached itself and rose, leaving the mineral clean; (2) others, especially galena and chalcocite, sank to the bottom but remained enveloped by an oil layer; (3) others, among them blende and iron pyrites, are intermediate between (1) and (2). They carry some oil with them, which they retain if quiescent, but if shaken, lose it. When the minerals are pulverized and mixed to a paste with water and oil, and then gently dropped on the oil surface as above, those of class (1) go to the bottom and those of class (2) are held by the oil layer. These phenomena do not occur unless the mineral is wet with water; if it is perfectly dry, all minerals behave like those of class (2).

The Radio-Activity of Allanite

In a paper to be presented at the fall meeting of the American Institute of Mining Engineers by L. S. Pratt of Charlottesville, Va., the author gives the results of a qualitative study of the radio-activity of several chemical substances and a few minerals. In the course of the work he studied the mineral allanite (obtained from granite ledges at Topsham, Me.) and found it to be appreciably radio-active.

Recently the fact was brought to his attention that the radio-activity of allanite is not well known, although Hon. R. J. Strutt in 1905 published a list of radio-active minerals with their analyses, including allanite from Amherst County, Va.

In the work done, a standard type of electroscope was used, and the readings were made with a telescope, fitted with a scale, by means of which the rate of discharge could be readily determined.

The natural "leak" of the instrument was carefully determined, and all results corrected accordingly.

The method of study was as follows: The material to be tested was finely powdered and spread over the bottom of a small inactive pan. The electroscope was then charged, and the pan placed in position. The door of the instrument was closed, and the rate of discharge carefully determined.

All results were reduced to common form to permit of comparison.

It is to be noted that the materials tested were not used in strictly comparable quantities, such as 1 g. of each had been used, but about the same quantity of powder was used (in the cases of the solid substances), so that the results are qualitatively accurate.

The results obtained were the following, reduced to common form and corrected for the natural "leak" of the instrument used:

	Mm. in 6 Min. (on Scale)
"Leak"	1
	Mm. in 6 Min.
Radium residue (in pan)	720
Thorium	62
Nernst mantle	17
Uranium nitrate	11
Allanite	3

Dyestuffs from Materials Native to Latin-American Countries

At the last Pan-American Scientific Congress Dr. SAMUEL T. SADTLER presented a paper dealing with the extraction of dyes from vegetable and animal sources, such as dyewoods and certain color-yielding insects, as against the manufacture of the synthetic or coal-tar dyes. Neither in Latin America nor in North America has the synthetic dye-color industry as yet been established upon so firm a commercial basis as to enable it to compete with the European dyestuff industry, although the present great war in Europe may, among other results, bring about such a result upon this side of the Atlantic.

The use of dyes of vegetable and animal origin long antedated the use of the synthetic dyes, and, indeed, down to the middle of the last century, when in 1856 Perkin discovered mauve, the first of the aniline dyes, the former were alone available.

The vegetable sources of the natural dyes are trees, shrubs, leaves and roots of plants. From these the dyestuffs are extracted by water or aqueous solvents, either with or without previous fermentation to decompose natural combinations like glucosides and liberate the dyestuff proper. These dyewoods and dye-yielding plants almost without exception are natives of tropical and semitropical countries, and some of the most important of them are especially to be found as natives of the Latin-American countries.

In taking up the vegetable and animal dyestuffs obtained from materials native to Latin-American countries for review, they are grouped according to color and their nature and occurrence described, together with their general uses. A table of natural dyestuffs with the artificial colors that have been used as substitutes, whether because of cheaper prices or their being faster to light and the action of reagents, is also given at length, as well as figures on production and imports into the United States.

Meeting of the American Chemical Society, University of Illinois, Urbana-Champaign

Report of General Sessions and Division of Industrial and Engineering Chemistry — Review of Exhibits

The present opportunity of American chemical industry, and the responsibility devolving upon American chemists in developing industrial independence in this country, were the dominant notes of the fifty-second meeting of the American Chemical Society, held at the University of Illinois, Urbana-Champaign, April 18-21, 1916. The registration of over 600 members and the presence of about 200 guests indicated the unusual interest now being shown in chemistry, and marked the climax in attendance at the society's meetings. The dedication of the new chemical laboratory of the University of Illinois lent additional interest and significance to the meeting. It was the occasion for special meetings and addresses, at which the speakers pointed out the need for educating more chemists and for more extended research in order to place our industries on a highly efficient basis. Of great value also was the exhibit of chemical apparatus and equipment for both laboratory and plant. The exhibit was well attended and provoked many expressions of its practical and educational usefulness. Even those visitors who were not directly engaged in industrial work must have gained new ideas, which will be useful in the future, either to themselves or their students. A complete list of exhibitors and their wares will be found at the end of this report. A number of new American products were shown for the first time, and brought home the fact that some of our resources are gradually being developed.

To the local committees of the society is due the greatest credit for the orderly and systematic arrangement of programs and excursions, and for the accommodation of such a large number of guests in a small college town. Only after the meeting was over and the guests departed could one really appreciate the time and thought that had been expended in making the gathering an unprecedented success.

Meeting of the Council

Several important matters were decided at the regular meeting of the council on Monday evening. The next meeting of the society will be held in New York next September, coincident with the Second National Exposition of Chemical Industries. The spring meeting for 1917 will be held at Kansas City, Mo., with a one-day session at the University of Kansas, Lawrence. New local sections of the society were authorized for Vermont and South Dakota.

It was definitely decided to proceed with the preparation and publication of the ten-year index of Chemical Abstracts. It was agreed that the time is especially propitious for this undertaking and that the index would be of great value to American chemists. The financial obligation for this undertaking will be about \$30,000. Members of the society already have pledged contributions of \$20,000, and it is the purpose of the society to raise the balance of the fund by public subscription in the chemical industries.

The council adopted the report of the committee on the "Westfield campaign" and Mr. Lewis B. Allyn's connection therewith. Based on the facts and evidence presented, no further action will be taken leading to

the expulsion of Mr. Allyn from the American Chemical Society. The really important feature of the report, which was given full publicity in the daily press, has reference to the ethics of special pure food movements, of which the so-called "Westfield campaign" is but one, and to chemists' relations therewith. The report disapproves the way in which such movements have been exploited by magazines and other publications in connection with their advertising columns, and considers them "altogether wrong in principle and opposed to the best interests of the public." Since financial profit from advertising is connected with such movements, they are not disinterested and are likely to create a bias which overlooks public interest in favor of private gain. A further reason for disapproving special campaigns of this sort is that they have not the large means to support continuous control by adequate technical staffs of high scientific standing. In order to satisfy an apparent public demand for positive information guaranteeing the purity of food and toilet articles, the committee urged that the society consider formulating plans to be laid before governing bodies which would lead to some kind of direct certification and guarantee of foods by Federal, State and larger municipal governments, or some other form of responsible control.

General Session

The meeting was formally opened at a general session held Tuesday morning in the large university auditorium, with Dr. W. A. NOYES, chairman of the University of Illinois Section, presiding.

In a pleasing address of welcome President EDMUND J. JAMES of the University of Illinois, sketched the manner in which our universities grow and develop, and showed that wholly unexpected lines of progress are sometimes forced on an institution in response to popular demand. As an instance, he cited the inception and growth of the department at Illinois devoted to ceramics and clay working. This department was established in 1908 as a result of the insistence and co-operation of Illinois clayworkers, who felt that the university should take a deeper interest in the industry. In the year of its establishment the department was housed in a building that cost \$1,000. Since that time the work has increased in volume and importance to the State, and increased facilities have been steadily demanded and provided, culminating in the recent completion of a structure costing \$140,000. Thus, in eight years, a new department has been developed as a result of keeping in close touch with the practical demands of local industry.

President CHARLES A. HERTY responded to the welcome, and expressed the society's appreciation of the cordial reception which the university had given visiting chemists. The keynote of Dr. Herty's address was the necessity of acquainting the great American public with a correct conception of the importance of chemistry in our industrial life. This requires a campaign of education on the part of every American chemist, be his interest and activity in the science educational or industrial. Upon technically trained men devolves a

responsibility to see that our daily newspapers and popular magazines get interviews and articles that will be authoritative and accurate. Dr. Herty referred to the appointment of the society's members on State committees that are engaged in gathering industrial information for the Naval Consulting Board. He commented also on the need of more research in this country and on a keener recognition of the importance of research in our schools. With considerable feeling he referred to the slowness with which we have awakened to the needs of some of our industries, notably dyes-stuffs, and called attention to the fact that insidious forces were at work to retard this industry, not on economic grounds but from deeper and baser motives that must be condemned.

Four papers of general interest followed the addresses. The first was an illustrated lecture by L. H. SMITH on *The Composition of Corn as Affected by Nineteen Generations of Seed Selection*. This long experiment in plant breeding had resulted in developing types of corn that are high and low in protein and high and low in oil content.

In his lecture on *The Manufacture of Chemical Apparatus in the United States* ARTHUR H. THOMAS presented the present status of the industry, and directed attention to our needs and the extent to which they are being met by domestic production.

The War and American Chemical Industry was the title of a paper by RAYMOND F. BACON. Numerous new products have been developed in the United States since the war threw us on our own resources. Among these the speaker referred to the present development of our potash deposits and the manufacture of American chemical porcelain.

A paper by G. H. A. CLOWES on *The Influence Exerted by Electrolytes on the Equilibrium of Emulsions, Jellies and Living Cells*, while apparently foreign to some phases of chemical engineering, nevertheless contained some fundamental matters bearing on the subject of surface tension.

The last paper on the list was that of JOHN JOHNSTON on *Some Effects of High Pressures*. In this lecture the author pointed out the similarity in the effect of pressure and temperature on certain reactions, but showed that much greater increases in pressure were required to accomplish results that could be as easily obtained with relatively small increases in temperature.

Meetings of Divisions

Beginning Wednesday morning the various divisions of the society met in separate session in the lecture rooms of the Chemistry Building. The total number of papers offered was 283, distributed as follows:

Agricultural and food chemistry.....	22
Biological chemistry.....	76
Industrial and engineering chemistry.....	26
Organic chemistry.....	52
Water, sewage and sanitation.....	28
Fertilizer chemistry.....	1
Physical and inorganic chemistry.....	62
Pharmaceutical chemistry.....	15

Only a casual glance at the number of papers offered is required to see that the programs were too congested. The condition was the subject of some comment to the effect that a stricter censorship should be exercised over papers accepted, in order to reduce the number and improve the quality. Another point that may be emphasized to the benefit of the society is the value of authors' abstracts or brief summaries. In the absence of publication prior to the meeting, it is almost essential to the success of the sessions that some outline be available to those who might be expected to take part in the discussions. Abstracts at the Urbana

meeting were conspicuous for their absence. Future meetings can be improved by not only asking authors to submit abstracts but requiring them to do so if their papers are to be placed on the program and read at the meeting.

Division of Industrial and Engineering Chemistry

The sessions of this division were presided over by H. E. HOWE, with S. H. SALISBURY, Jr., as secretary. The program was marked by the diversity of papers, which covered subjects from bread-making to coal-sampling, and soap to coal tar.

A *New Form of Adiabatic Calorimeter* was described by S. W. PARR, who explained that there is a constant tendency toward making calorimetry more exact by developing improved forms of apparatus. The latest calorimeter is the adiabatic, in which the temperatures of the inner and outer bodies of water are kept equal, so that there will be no flow of the heat developed in the combustion.

The same author discussed *The Determination of Ash in Coals with a High Percentage of Calcium Carbonate*. Many of the central and eastern coals contain so much calcium carbonate that it interferes seriously with the exact and uniform determination of ash. In burning the coal the lime may form CaO or CaSO₄, or part of it may remain unchanged as CaCO₃. The variations between the determined and true ash, when the former is made in the usual manner, will be from 2 per cent to 4 per cent. Uniform results can be obtained by first converting the carbonate to sulphate through the addition of sulphuric acid and burning at a temperature not higher than 750 deg. C. The quantity of calcium carbonate originally present is then calculated from determinations of SO₄ made on original coal and sulphated ash. When made in this way, determinations of ash on limey coals will check within 0.05 per cent to 0.5 per cent.

The Mechanical Sampling of Illinois Coal also was presented by Mr. PARR. The author called attention to the necessity of employing high-grade talent and ability in taking and preparing coal samples. He showed that the ash content of a sample as usually prepared varied in the different screen sizes of the sample, increasing with the fineness. A type of Sturtevant mill modified by the author has given uniform results in mechanical sampling, so that some of the former errors have been eliminated.

An Investigation of Composition Flooring, by R. F. BACON and R. R. SHIVELY, embodied the results of some work done at the Mellon Institute on compositions of magnesia, sawdust, terra alba, infusorial earth, clay and magnesium chloride. The investigation was concerned with the difficulties encountered in preparing floorings from the materials mentioned, and with methods for overcoming the troubles.

The Use of Certain Yeast Nutriments in Bread-Making. By H. A. KOHMAN.

A paper on *Hydrated Lime* by J. F. MACKEY presented a study of the active and inactive values of ground hydrated lime, and of the influence of grinding on the hydraulic value of various sized particles. Finer grinding increases the active value of hydrated lime. The effect of hydrated lime on Portland cements was studied by mixing various percentages of lime with cement, up to 20 per cent lime. The strength of neat cement is decreased by such additions, but the strength of cement mortars is increased.

Further Experiments on the Volatilization of Platinum were described by G. K. BURGESS and R. G. WALTENBERG, being a continuation of some work previously



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reported. Losses of platinum over a Bunsen burner are negligible. In fact, there may be a slight gain due to oxidation of iron, which is a constituent of all platinum. The effects of iridium, rhodium and silicon were discussed.

W. D. ENGLE and R. G. GUSTAVSON presented the results of a new method for the *Volumetric Determination of Cobalt and Nickel*. The separation of these elements is regarded as difficult and tedious, but the authors showed that cobalt could be easily determined in the presence of nickel by oxidation with NaBO_2 in alkaline solution, removing the excess of NaBO_2 by boiling and, after addition of KI and dilute H_2SO_4 , titrating the liberated iodine with standard sodium thiosulphate. They also showed that nickel does not give concordant results when similarly treated with more powerful oxidizing agents, such as bromine water and potassium persulphate.

The Deposition of Copper in Electrotyping Baths

This paper was offered as a preliminary report by W. BLUM, H. D. HOLLER, H. RAWDON and E. L. LASIER. The work was initiated at the request of the Government Printing Office, and was conducted in co-operation with the International Association of Electrotypers. The methods of study employed and the properties and structure of the copper deposits were illustrated by specimens and photographs. The latter will be included in the publication of the completed work, which will be issued as a technologic paper of the Bureau of Standards. Notice of its issue will be given later. The following summary of the work is given.

Properties of Deposited Copper.—(a) In general, the finer the crystals the higher is the tensile strength and, therefore, probably, the hardness of the copper. With low-current densities, especially at high temperature, the copper possesses a relatively coarse columnar structure, except just at the initial surface of deposition, where the metal is always in relatively fine crystals. With increasing current density, especially at low temperature, the structure becomes less regular, showing frequent evidences of twinning.

Preliminary tests show that a decided decrease in tensile strength is produced by annealing these thin specimens for even 15 min. at temperatures from 200 deg. to 400 deg. C. (400 deg. to 750 deg. Fahr.).

(b) The ductility (as measured by the permanent elongation after fracture, increases with increased tensile strength up to a tensile strength of about 2800 kg. per cm^2 (40,000 lb. per square inch) and then decreases, i.e., the copper becomes relatively brittle.

(c) It is believed that copper with a tensile strength of 2500 to 2800 kg. per cm^2 (35,000 to 40,000 lb. per square inch) and an elongation of 20 to 30 per cent will be found satisfactory for electrotype plates.

Agitation.—The best possible agitation should be employed, especially between the anodes and cathodes.

Composition of Solutions.—(a) Under otherwise uniform conditions an increase in the amount of copper sulphate causes a slight increase in tensile strength.

(b) Under otherwise uniform conditions, an addition of sulphuric acid at low temperature (25 deg. C. or 77 deg. F.) causes an increase in tensile strength; and at

high temperature (40 deg. C. or 104 deg. F.) causes a decrease in tensile strength.

(c) The solution should contain from 50 to 80 g. per liter (7 to 11 oz. per gal.) of sulphuric acid, and from 250 to 200 g. per liter (34 to 27 oz. per gal.) of copper sulphate. The specific gravity of the solution should be from 1.17 to 1.18 (21 deg. to 22 deg. Baume).

(d) Whatever the composition employed, it should be kept as nearly constant as possible, to insure uniform working conditions.

Temperature.—(a) A rise in temperature under otherwise uniform conditions always decreases the tensile strength. This effect is most marked with high acid content and with medium current density.

(b) The solution should be maintained between 25 deg. and 30 deg. C. (77 deg. to 86 deg. F.), unless high current densities are used (over 8 amp. per dm², or 75 amp. per square foot), in which case the temperature may be allowed to rise to 35 deg. C. (95 deg. F.).

Current Density.—(a) At low temperature the higher the current density (up to 9.5 amp. per dm², or 90 amp. per square foot) the higher the tensile strength of the copper. Good results can be obtained from 4.5 to 9.5 amp. per dm² (40 to 90 amp. per square foot).

(b) At high temperature an increase in current density from 2.5 to 4.5 amp. per dm² (about 25 to 40 amp. per square foot) causes a decrease in tensile strength. With current densities from 4.5 to 10.5 amp. per dm² (40 to 100 amp. per square foot) the tensile strength increases. At 35 deg. C. (95 deg. F.) current densities of 8 to 10 amp. per dm² (about 75 to 95 amp. per square foot) will yield the most satisfactory deposits.

Thickness and Distribution of the Copper.—On smooth or half-tone surfaces the thickness of copper will usually be from 80 to 90 per cent of that calculated for the time and current used. On type surfaces the copper will be only 30 to 50 per cent as thick as calculated.

The closing paper of the Wednesday session of this division was given by JAMES R. WITHEROW on *Unnecessary Waste of Potash Compounds*. The author showed that we have been in the habit of using many potassium compounds where similar sodium compounds would do just as well. Our textbooks and laboratory manuals prescribe experiments with potash material when soda would serve the same illustrative purpose. This habit, established in the classroom and laboratory, has been extended to commercial operations, with the result that we have been guilty of a gross waste of potassium. Chemists must bear this matter in mind and conserve potassium wherever possible by using sodium as a substitute when the same result can be obtained.

Dedication of Chemistry Building

The dedicatory exercises of Wednesday afternoon were held in the university auditorium, W. L. ABBOTT, president of the Board of Trustees of the University of Illinois, presiding. The Rev. GEORGE P. HOSTER of Champaign, read from the Scripture and offered prayer, after which the audience joined in singing "Illinois."

The opening address was given by President JAMES of the university, in which he discussed the question of whether a great university is built up of men and brains or of structures and equipment. While formerly he had inclined to the view that too much money was spent on mere piles of brick and stone, and not enough on brains, he had changed his mind and had come to believe that the physical appearance and equipment of a university was a large factor in its success. In the case of the new chemistry building he felt that its very appearance and magnitude must inspire men with the importance of chemistry at Illinois and in this country.

In regard to the work of the chemistry staff, President James said he considered there were three duties to keep in mind: First, to conduct a teaching enterprise, in which the youth was encouraged to take an interest in his subject; second, to make contributions to science through investigation and research; and, third, to let the world know what chemistry is doing for the welfare of the people, and to spread general knowledge of science among the people through popular publications and lectures.

The Training of Chemists was the subject of the next address by ALEXANDER SMITH, professor of chemistry at Columbia University. Dr. Smith took up in some detail the methods of training chemists, believing that careful training is a prerequisite to research and that the advancement of the science must depend not on the discovery of a few geniuses but on the proper training of a great body of men. The address covered many points in methods of instruction and on the mechanical arrangement and equipment of laboratories that must be of value to chemists engaged in educational work.

The final address was given by Dr. W. R. WHITNEY on *Research as a National Duty*. Dr. Whitney stirred his audience by some informal remarks prefatory to his address, in which he made it clear that if we want to know "who's who among the nations," we must look for the amount and quality of research work under way or accomplished. In his opinion research will ultimately determine "who's who." Advance is not made by thought alone, but by mixing brains and matter. Progress is slow as long as we merely speculate, but rapid when we think and act. In the use of science this country has much to learn, and in research we are as yet children. Our colleges and universities must lay more stress on research, for many of those institutions are still better known for their foot work rather than for head work. Research is preparing in one decade for the problems of the next, and the best type of national preparedness is research begun in time and conducted continuously. No nation can be effective in research conducted at odd moments; it must be persistent and continuous.

Following Dr. Whitney's address the audience sang "America," and adjourned to the Chemistry Building, where an informal reception was held and the various laboratories inspected.

Further Papers on Industrial and Engineering Chemistry

The Chemistry and Technology of Glass was presented in an illustrated lecture by ALEXANDER SILVERMAN, who exhibited various forms of blown, molded and pressed glass. In discussing the composition of colored glasses, the speaker demonstrated the similarity in color phenomena shown by different materials in both vitreous and liquid solutions. The lecture was followed by an informal talk by Prof. MORGAN BROOKS of the University of Illinois, representing the Society of Illuminating Engineers, who discussed the properties of glass used in globes for interior and street lighting.

In a progress report from the Forest Products Laboratory, Madison, Wis., F. W. KRESSMAN discussed the production of *Ethyl Alcohol from Wood Waste*, showing the yields of alcohol from various woods. Among coniferous woods the yields are as follows: White spruce, 8.54 per cent; red spruce, 8 per cent; Southern white pine, 8.3 per cent; Idaho white pine, 7.75 per cent. The yield from broad-leaf woods, such as beech, birch and maple, is lower, ranging from 3 per cent to 4 per cent.

The Cooking of Soda Pulp, by SIDNEY D. WELLS, was a further contribution from the Forest Products Laboratory, with special reference to the effect of moisture introduced into the digester.

Notes on Tar from Some Mid-Western Cannel Coals, by J. C. INGRAM. In this paper the author gave the results of low-temperature distillation of some Missouri and Illinois coals, the work having been undertaken to compare the properties of the tar distillate with that obtained from the oil shales of Utah and Colorado. The coal was distilled in gasoline-fired iron retorts holding about 50 lb. At a temperature between 700 and 800 deg. the yield was from 30 to 45 gal. tar per ton of coal. The following fractions were obtained from the tar.

Temperature Degrees	Percentage Yield	Specific Gravity
Up to 150	12	0.752
150-200	6	0.788
200-240	9	0.820
240-270	8	0.850
270-300	16	0.912
300 to coke	35	0.945

The fractions 200-240 and higher all oxidize rapidly, changing from colorless to colored oils. Of particular interest is the fraction 150-200, which has been tested as a flotation oil with encouraging results. This fraction is reported to show a high selective action.

The Recovery of Glycerole in the Krebitz Process of Soap Manufacture was discussed by G. S. WRISLEY. The Krebitz process yields the theoretical quantity of glycerole indicated in the reaction between stearin and lime. The lime soap formed in this reaction is then decomposed with soda ash, giving soda soap and calcium carbonate. A yield of 95 per cent glycerole is now being obtained by this process, compared with 60 per cent to 75 per cent by former processes. Under present economic and industrial conditions the Krebitz process is more profitable than other methods.

An Unusual Explosion in Connection with Potassium Chlorate was described by F. E. ROWLAND, who exhibited the pieces of a mortar and pestle that had been broken by an explosion that occurred while grinding potassium chlorate. The exhibit showed that the wooden handle of the pestle had been set in sulphur, some of which had apparently become dislodged and mixed with the chlorate during grinding.

The Effect of Ageing on the Constants of Chinese Wood Oil was shown in a paper by D. F. MCFARLAND and H. R. LEE. The work extended over a period of eight years, during which time the iodine number decreased from 171 to 166; the soap number increased from 190.9 to 195.2; the acid number increased from 4.5 to 6.6; specific gravity increased from 0.9423 to 0.9452, and the refractive index also increased.

Two papers were presented by L. V. REDMAN, A. J. WEITH and F. P. BROCK, on *Fillers in Synthetic Molding Compounds and Printing Plates from Phenol Resins*.

The final papers were by W. K. LEWIS on *The Principles of Counter-Current Extraction; Flow of Viscous Solutions Through Pipes; The Use of the Pound Mol in Gas Calculations, and the Flow of Heat from Solids to Air*.

In the Division of Physical and Inorganic Chemistry, LOUIS KAHLENBERG and K. P. YOUNG described a new method for the *Separation of Aluminium from Zinc, Manganese, Nickel, Cobalt, Iron and Chromium*, which should prove valuable. Aluminium is precipitated with ammonium salicylate, giving a crystalline precipitate of aluminium salicylate that can be ignited directly to the oxide. The separation is complete, with the possible necessity of reprecipitation to prevent occlusion of the other metals.

A method for the *Extraction of Radium from Carnotite Ores*, as given by A. G. LOOMIS and HERMAN SCHLUNDT, is based on the decomposition of the ore with sulphuric acid or salt cake, giving at once an ex-

traction of all the valuable metals by means of a cheap reagent.

The sessions at Urbana were closed with two public lectures, complimentary to the citizens of Urbana and Champaign, by CHARLES L. PARSONS on the *Production of Radium*, and CURTIS F. BURNAM on the *Use of Radium in the Treatment of Cancer*. The lectures were illustrated by lantern slides and moving pictures, and were largely attended.

Excursions

Under the direction of D. F. MCFARLAND and committee a number of interesting excursions were arranged. Two afternoons were devoted to an inspection of the extensive laboratories and departments of the university. On Friday about 200 of the visitors went to Danville by special train, where they visited the works of the Hegeler Zinc Co., the Carbon Hill Strip Mine of the Two Rivers Coal Co., the Western Brick Co., and the Illinois Window Glass Co. At Danville a complimentary luncheon was served by the Danville Chamber of Commerce, and automobiles were provided for trips to the glass works and about the city.

At the Hegeler Zinc Company's plant the visitors witnessed all the operations incident to the production of spelter, including the preparation of the ore and coal, charging and discharging of the retorts and casting of spelter, production of sulphuric acid from the roaster gases and the making of retorts and condensers. The smelting equipment consists of six blocks of 900 retorts each, and the output is 75 tons of spelter per day. The production of 60-deg. Be. chamber acid amounts to 150 tons per day.

Entertainment

Visiting ladies were well entertained at a series of receptions, concerts and luncheons. The principal function for the men, which was attended by ladies also, was the smoker given in the large gymnasium annex. About 800 persons enjoyed the fun provided on this occasion, which was enlivened by moving pictures, of local production, showing "Prof. Dr. Escroc Fumiste, Professor of Pathological Chemistry at the University of Monte Carlo," in a series of remarkable chemical experiments. His most striking experiment was on electrical conductance and ionization, in which he showed that a material which contains no ions (Kahlenberg's Chemistry) is a non-conductor of electricity; but on treating the material with a strongly ionizing solvent a transformation takes place. On examination, the new material (Alexander Smith's Chemistry) is found to be a conductor of electricity and to contain ions.

Two informal dinners were tendered to members of the chemical fraternities by the local chapters of Alpha Chi Sigma and Phi Lambda Upsilon.

"International Harmony," presented by members of the Cosmopolitan Club of the university, afforded further entertainment in the form of foreign songs and dances. The formal banquet served in the Masonic Temple was a brilliant affair attended by about 400 members and guests. President HERTY introduced Dr. BOGART of Columbia University, who presided as toastmaster and delighted the audience with his stories and witty references to the other speakers. Responses were made by GEORGE B. FRANKFORTH of Minnesota, LOUIS KAHLENBERG of Wisconsin, W. D. BANCROFT of Cornell, WILLIAM B. MCKINLEY, congressman for the Nineteenth District of Illinois, and HENRY P. TALBOT of Massachusetts Institute of Technology.

Exhibit of Chemical Apparatus, Equipment and Products

One of the most attractive and valuable features of the meeting was the exhibition in the basement of the



Exhibits at Urbana Meeting, American Chemical Society

Central Scientific Co., Thermal Syndicate, Duriron Castings Co., General Electric Co., Abbé Engineering Co., Schutte & Koerting, Scientific Materials Co., Sweetland Filter Press Co., U. S. Bottling Machinery Co., Permutit Co., Sharples Specialty Co., Herold China & Pottery Co., Thwing Instrument Co., Schaefer & Budenberg, Elyria Enamelled Products Co., Sowers Mfg. Co., Celluloid Zapon Co., METALLURGICAL AND CHEMICAL ENGINEERING.



EXHIBITS OF PFAUDLER CO., EIMER & AMEND, MACBETH-EVANS GLASS CO., AND RUBBER MUSEUM AT MEETING OF AMERICAN CHEMICAL SOCIETY, URBANA, ILL.

new chemistry building. This was arranged by the courtesy of the university under the direction of H. L. OLIN and committee. Following is a complete list of concerns participating, their representatives in attendance, and products:

ABBE ENGINEERING Co., New York; Howard C. Russ. Combination 4-jar porcelain ball and pebble mill, operated by motor; rotary high-vacuum pump operated by motor and connected with mercury gage showing column of 29.9 in. when barometer stood at 30 in.; rotary pressure blower; De Rycke steam separator and grease extractor; hard lead centrifugal acid pump.

AMERICAN COAL AND BY-PRODUCTS COKE Co., Chicago; Prof. H. McCormick, Donald Riley. Blue prints of oven designs; samples of coke from Illinois coals; heating wall exhibit.

ARMOUR AMMONIA WORKS, Chicago; J. R. Powell. Anhydrous ammonia tanks.

P. BLAKISTON'S SONS Co., Philadelphia; G. E. Morehead. Technical Books.

BRAUN CORPORATION, Los Angeles, Cal. Apparatus for electro-analysis.

CELLULOSE ZAPON Co., Chicago; Lyn E. Sturdevant. Lacquer materials and products.

CENTRAL SCIENTIFIC Co., Chicago; J. M. Roberts, A. H. McConnell, Capt. A. D. Khotinsky, S. L. Redman. DeKhotinsky constant temperature apparatus; American-made laboratory glassware, porcelain, balances and weights; laboratory electrical instruments.

DEARBORN CHEMICAL Co., Chicago; D. K. French. Boiler tubes; typical examples of flue corrosion.

J. P. DEVINE Co., Buffalo, N. Y.; Philip L. Davis. Photographs of typical vacuum drying apparatus and chemical machinery.

DURIRON CASTINGS Co., New York and Dayton, Ohio;

J. S. Miller, Jr. Duriron pipes and fittings, showing different methods of connecting lines; various pieces of Duriron apparatus, among the larger pieces being centrifugal pumps, suction fans, 6-in. globe valve; a new alloy in the form of a No. 45 crucible, which has been developed for the melting of aluminium.

EIMER & AMEND, New York; E. Child, sales manager, and T. M. Saulters of the Pittsburgh department. Complete line of laboratory supplies, consisting largely of the company's specialties, among which were: new Frees electric vacuum oven, chain vernier analytical balance, Veit electro-analysis apparatus, multiple-unit electric furnaces of the muffle and other types. A comprehensive assortment of Pyrex glassware and Cor's Colorado chemical porcelain. Bailey-Walker extraction apparatus, new type May Nelson high-vacuum pump, Wysor metallographic combined grinding and polishing machine, miscellaneous small apparatus.

ELYRIA ENAMELED PRODUCTS Co., Elyria, Ohio; J. E. Simpson, E. P. Poste, W. E. Gray, Jr. Acid and alkali-resisting, seamless, glass-lined steel apparatus.

GENERAL ELECTRIC Co., Research Laboratory, Schenectady, N. Y. In general this was the same exhibit shown by the company at the Panama-Pacific International Exposition. Coolidge X-ray tube and X-ray plates showing varied application in branches of science, such as examinations of castings, rifle cartridges, shot-gun shells, built-up mica, etc. Plates showing recent laboratory work on crystal structure and metallic spectra. Tungsten and its products; steps in making tungsten from ore, and applications of wrought tungsten. Calorized iron and copper pipes, pyrometer tubes and crucibles, resistant to oxidation at high temperatures. Vacuum and gas-filled Mazda lamps, showing increase in efficiency from three watts per candle to one-half

watt. Arsem vacuum furnace, developing temperatures up to 3000 deg. C.

HEROLD CHINA & POTTERY Co., Golden, Colo.; C. F. Quaintance. Coor's U. S. A. chemical porcelain made from Colorado clays; glazed and unglazed ware for chemical and electrochemical work; subjected to heat and chemical tests.

LABORATORY SUPPLY Co., Columbus, Ohio; Robert C. Schroth, Jr. "Circle S" brand of "Made in America" laboratory specialties: laboratory porcelain, rubber zoods, microscope slides, laboratory wire and sheet-metal goods, filter paper.

LEEDS & NORTHRUP Co., Philadelphia; S. C. Redding, I. B. Smith. Complete equipment for electric conductivity measurements, according to Dr. E. W. Washburn, with several sources of high-frequency current, including the Vreeland oscillator and a 1000-cycle inductive generator. Potentiometer equipment for hydrogen ion concentration determination. Wheatstone bridges, resistance boxes, galvanometers.

LENZ & NAUMANN, INC., New York; Francis W. Reese. Lenzmann Insol glassware; laboratory supplies and chemical apparatus.

LONGMANS, GREEN & Co., New York; G. E. Morehead. Scientific books.

MACBETH-EVANS GLASS Co., Pittsburgh; J. M. Barnett, D. E. Ellis. Chemical glassware.

MCGRAW-HILL BOOK Co., New York; M. L. Foss. Technical books.

MCINTOSH STEREOPTICON Co., Chicago. Stereopticons used in sessions.

METALLURGICAL & CHEMICAL ENGINEERING, New York. J. M. Muir, J. C. Munn, H. C. Parmelee.

MISHAWAKA WOOLEN MFG. Co., Mishawaka, Ind.; C. E. Bradley. Exhibit of process of making rubber and cloth products, together with finished materials.

MITCHELL LIME Co., Mitchell, Ind. Lime products.

MOJONNIER BROS. Co., Chicago; J. J. Mojonnier. Milk and food testing apparatus; high efficiency vacuum drying ovens; combination cooler and desiccator; vacuum pumps.

NATIONAL CARBON Co., Cleveland, Ohio; William C. Moore, M. E. Holmes. Columbia dry cells; wet cells; motor and generator brushes; carbon specialties; arc carbons; carbon electrodes.

NATIONAL LEAD Co., Chicago; L. T. Wilson, Vance Buckner, Prof. A. H. Sabin. Lead pigments and lead base alloys.

NORTON COMPANY, Worcester, Mass. Alundum products.

PALO COMPANY, New York. Recording thermometers.

PERMUTIT COMPANY, New York and Chicago; B. M. Ferguson. Permutit water-softening filter in operation; Permutit demonstrating kit; samples of Permutit ingredients; Permutit products.

PAUDLER COMPANY, Rochester, N. Y.; N. G. Williams, F. L. Craddock, R. B. Kilmer. Steam-jacketed seamless glass-enameled mixing tank with enameled agitator; upright open one-piece glass-enameled tank.

SARCO COMPANY, INC., New York; George B. Burke. Sarco tank-temperature regulators, steam traps, room-temperature regulators and radiator traps.

SCHAEFFER & BUDENBERG MFG. Co., Brooklyn, N. Y.; A. H. Reuter. Recording gages, draft gages, indicating and industrial thermometers and vacuum gages.

SCHUTTE & KOERTING, Philadelphia. Nozzles, ejectors, valves.

SCIENTIFIC MATERIALS Co., Pittsburgh; L. W. Hoshour, H. W. Seldon. General line of laboratory supplies and specialties, among them being: Scimatco optical bench, Scimatco hardness testing machine with a special depth gage, Fry resistance glassware, Royal

Copenhagen porcelain, complete Burrell gas analysis apparatus, Scimatco burners. Samples of Scimatco laboratory tubing were distributed.

SHARPLES SPECIALTY Co., West Chester, Pa., and Chicago; P. T. Sharples, Max B. Miller. Super-centrifuges for both laboratory and commercial work.

SOWERS MFG. Co., Buffalo, N. Y.; B. W. Collins. Dopp steam-jacketed seamless kettle; also kettle in cross-section showing method of construction.

E. R. SQUIBB & SONS, New York; F. M. Schad, C. Hahn. First showing of Squibb analyzed chemical reagents.

STANDARD CALORIMETER Co., East Moline, Ill.; Prof. S. W. Parr, S. Seaberg. Sulphur photometer; Parr peroxide calorimeter; blast lamps; Parr adiabatic calorimeter; Parr gas calorimeter; Parr oxygen bomb calorimeter; total carbon apparatus.

SWEETLAND FILTER PRESS Co., New York; F. W. Manning. Sweetland self-dumping demonstrating press in operation, equipped with filter leaves covered with Sweetland patented metallic cloth.

TAYLOR INSTRUMENT Co., Rochester, N. Y.; H. W. Maurer, H. Pagenstecher. Mercury-operated recording and indicating thermometers; special thermometer sockets made of various acid-resisting materials.

THERMAL SYNDICATE, New York; William W. Winship. Vitreosil ware for various purposes and in special pieces: acid plant details, laboratory utensils, tubes, pyrometer protecting sheaths and insulators.

THWING INSTRUMENT Co., Philadelphia; Dr. C. B. Thwing. Multiple-record recorders, thermocouples, indicating and radiation pyrometers.

TOCH BROTHERS, New York. Paints and enamels for technical use.

U. S. BOTTLERS MACHINERY Co., Chicago; A. J. Pohlman. U. S. drum multiple-disc filter presses.

U. S. METALS REFINING Co., Chrome, N. J. Rare metals and chemicals.

WALRUS MFG. Co., Decatur, Ill.; C. E. Beckman. Laboratory furniture; A'berene tops, shelves and sinks.

JOHN WILEY & SONS, INC., New York; J. H. Needler. Scientific books.

Museum of Rubber and Its Products

THE MANHATTAN RUBBER MANUFACTURING COMPANY, Passaic, N. J. Raw wild and plantation rubbers, and a variety of rubber products.

TYSON BROTHERS, Stamford, Conn. White and black rubber substitutes, rubber pigments, and special adhesives.

GABRIEL & SCHALL, New York City. Zinc oxide, barium sulfate, and lithopone.

CORN PRODUCTS REFINING COMPANY, New York City. Exhibit showing the stages in manufacture of black and white rubber substitutes from corn oil.

STAMFORD RUBBER SUPPLY COMPANY, Stamford, Conn. White and black rubber substitute and antimony pigments.

RACINE TIRE COMPANY, Racine, Wis. Exhibit showing every step in the manufacture of automobile tires from the various raw rubbers to the finished tire.

JOSEPH DIXON CRUCIBLE COMPANY. Graphites used in rubber manufacturing.

FAULTLESS RUBBER COMPANY, Ashland, Ohio. Exhibit of over fifty different kinds of druggists' sundries made from rubber, including all sizes and colors of hot water bottles, rubber tubings, rubber sponges, syringes, gloves, etc.

RAVEN MINING COMPANY of Utah. Samples of Kapak, a refined elaterite used in rubber work.

Books on rubber from the India Rubber Publishing Company were also on exhibition.

Coal-Gas Residuals and Their Application*

BY FRED H. WAGNER

Chief Engineer The Bartlett Hayward Company

The destructive distillation of coal, as practised to-day, may be divided into two classes, the first being that practised in gas works, the second being the one practised by the coke-oven operator. The latter method of distillation, or carbonization, may also be subdivided into two classes, or distillation with by-product recovery, and bee-hive oven distillation; as the latter yields no other product than coke, it will not be given any further consideration.

These two classes of distillation, or carbonization, lead to two very different methods of operation; the object of the gas-work operator is to produce a maximum yield of gas possessing certain required qualities, such as candle-power and thermal value, with the recovery of certain by-products, while the object of the coke-oven operator is to produce a maximum of low-volatile coke, the recovery of by-products, in some instances, being entirely neglected.

The quantity of gas produced, as well as the production of coke and other by-products, is entirely dependent upon the character of the coal distilled, as well as on the character of the carbonizing plant. Gas intended for cooking or illuminating purposes must possess certain characteristics, and must consequently be purified, as the crude gas contains substances which are of a harmful character, and, if retained in the gas, these substances would be liberated during combustion; but these substances all possess a commercial value, and, with the exception of coke and retort graphite, the by-products secured from a gas works are therefore due to the necessity of cleaning the gas before it can be used for domestic purposes.

The principal by-products consist of coke, retort graphite, tar, naphthalene, ammonia, cyanogen and sulphur. Owing to the necessity, in many cases, of selling domestic gas on a candle-power basis, it is not advisable to remove such valuable products as benzol and toluol from the gas works product, and, as a rule, these constituents must therefore be sought in the products from the coke oven.

The appended diagram, adapted from one prepared by W. J. Butterfield, approximates the average yield of primary products, the return of secondary products secured from the primary, as well as the ultimate yield of some of the more important subsequent products, the amounts secured being based on the distillation of 100 tons of coal in gas works practice.

While this diagram gives the total amount of coke produced as 70 tons per 100 tons of coal carbonized, the amount of coke of salable size will hardly average more than 50 tons, and often less, due to the amount used as fuel in the producers which supply the heat required for distillation, and to the amount of breeze produced by handling. In Germany this coke breeze is worked up into briquettes, but little has been done in this particular in this country, probably due to our still illimitable supply of coal, and to our negligence in the conservation of our resources.

The salable coke produced in coke ovens amounts to from 60 to 65 per cent of the weight of coal carbonized, this latter coke being distinguishable from gas-works coke in that it is better adapted for metallurgical purposes.

The amount of graphite produced in the retort is dependent upon the type of retort used, as well as on the heat of carbonization employed, also on the charac-

ter of the coal distilled; this graphite has quite some commercial value.

The moment the gas is released from the coal, and when it is subjected to cooling, it begins to condense and to drop various compounds of a hydrocarbon nature, these compounds being deposited in conjunction with an aqueous solution of ammonia salts combined with dust and soot; these hydrocarbon substances, together with the dust and soot, form tar.

After the gas has been subjected to this process of cooling, or after the tar and a portion of the ammonia compounds have been removed, the gas is usually subjected to a washing process for the removal of the remaining ammonia or the ammonia may be directly absorbed by passing the gas through a sulphuric acid bath.

The cyanogen in the gas may be removed either before or after the removal of the ammonia, the gas, in the first case, being washed with an iron solution with the consequent formation of ammonium ferrous-ferricyanide, this being an insoluble product, while in the second case the gas is washed with a solution of hydrated lime and iron, this latter product being a soluble one, these products are generally converted into potassium ferrocyanide, commonly known as yellow prussiate of potash, or into sodium ferrocyanide. At present the removal of cyanogen from coal gas is a very profitable investment, but besides this, its removal is of a distinct advantage in operation, as the presence of cyanogen has a very deleterious effect on all steel work, and especially on gas-holder sheets.

The sulphur compounds are usually removed in the purifiers, but a portion is absorbed during the process of washing and condensing; this constituent, principally in the form of hydrogen sulphide, is usually absorbed by oxide of iron, but little lime being used for this purpose to-day. The sulphur thus absorbed is removed from the oxide of iron and converted into sulphuric acid. Unless special requirements call for the removal of carbon bisulphide it is retained in the gas, as its removal entails quite some difficulties and its economy is open to question.

The apparatus usually employed in gas works practice is so constructed as to remove not only the so-called impurities, but also valuable by-products by condensation and absorption, the removal by condensation being due to the fact that the coal is distilled at very high temperatures, thus causing the formation of various gaseous products which do not remain in the gaseous state at ordinary temperatures, and which are therefore readily removed during the process of cooling.

This short explanation of the method of operation and the statement of the nature of the by-products to be expected enables us to give a more detailed description of the products and their uses.

Coke

Coke is the first by-product obtained through the dry distillation of coal, and it is the residue left in the retort or oven chamber after the volatile products have been driven off. The composition of the coke is, of course, dependent upon the character of the coal carbonized; it is hard and brittle, and varies in color from very dark to silver gray, being composed of highly complex compounds of carbon, hydrogen, oxygen, nitrogen and sulphur. The porosity or density of coke is dependent upon the type of retort used for distilling and upon the method of quenching and handling the coke after it has been ejected from the retort; in gas works practice vertical retorts produce a coke of maximum density, due to the fact that the weight of the coke itself causes a

*A paper read before the Franklin Institute of Philadelphia.

sintering of the coke particles. Gas works coke is generally used for domestic purposes, the metallurgist depending in most cases on the product received from the coke oven.

The late Prof. Vivian B. Lewes of England said: "Among the factors that lead to the commercial supremacy of a country, by far the most important is the command of fuel or other source of power; and England's position in the past has been governed largely by her coal fields, which in little more than a century raised her to the forefront as a commercial power. The very abundance of our coal supplies was a source of weakness, as it led to outrageous waste, polluted our atmosphere to a criminal extent and so encouraged uneconomical methods of using it as seriously to deplete our available stock, the result of which has been the increase in price during the last few years and the certainty that the future will see further advances but no fall to the old rates. The day of cheap coal has gone, never to return."

If this statement is true for England, how much more so is it applicable to our own conditions, where so much remains to be done in conserving our fuel beds, and this conservation can be greatly aided by a concerted effort to educate the user in the benefits to be derived from the burning of coke; but, here again, we find that in the manufacture of metallurgical coke the warning has not been heeded, and this industry in many instances exhibits a prolific waste which is almost criminal. The change from the bee-hive to the by-product oven is very slow, but it is progressing; we find that in 1893 the bee-hive ovens produced 9,464,730 short tons of coke, the by-product ovens producing only 12,850 tons during this same period; in 1901 the product was: bee-hive ovens, 20,615,983; tons by-product ovens, 1,179,900 tons; in 1910 bee-hive ovens, 34,570,076 tons; by-product ovens, 7,138,734 tons, and in 1913 the bee-hive oven product amounted to 33,584,830 tons, while that from the by-product ovens was 12,714,700 tons. It is true that the total consumption of coke has increased, but while that produced by the bee-hive ovens in 1893 amounted to 99.99 per cent of the total, this was decreased to 94.59 per cent in 1901, to 82.88 per cent in 1910 and to 72.54 per cent in 1913.

A series of tests made by the American Radiator Company to determine the efficiency of domestic fuels showed that gas coke of nut size led the list with an efficiency of 78.7 per cent, followed by gas coke of egg size with 75.43 per cent; Pittsburgh coke with 71.40 per cent, anthracite coal with 66.30 per cent and Pocahontas coal with 66.10 per cent. It was also shown that in case of kindling Pocahontas coal stood first, but gas coke of nut size was a close second, followed by gas coke of egg size, Pittsburgh coke and anthracite coal last. Gas coke burns with an even, smokeless fire, it is easily controlled and clean to handle. It is also probably the most economical fuel in the market, and there is no reason why it should not displace many forms of domestic fuel now in use, thus greatly assisting in conserving our coal supply and adding benzol and toluol, with their subsequent products, to our source of national wealth.

Retort Graphite

Retort graphite is produced by the decomposition of the hydrocarbons in the gas, these latter constituents having been deposited on the walls of the retort. Owing to its poor heat-conducting qualities, it must be removed periodically from the inside of the retorts, clay retorts requiring more frequent cleaning periods than do those made of silica.

This graphite has found its most important application in the production of carbon electrodes, the raw

graphite being thoroughly cleaned, crushed into a powder and then formed into a plastic mass by the admixture of coal-tar and lampblack. This mass is formed into rods by passing it through a hydraulic press.

The rod thus formed is then baked in kiln, where the coal-tar is decomposed by heat, producing graphitic carbon, which combines with the retort graphite and forms a hard but brittle mass.

Tar

Tar is chiefly removed from the gas by progressive condensation, and when removed in this manner is accompanied by so-called gas liquor, or ammonia liquor, these two liquids being later separated by virtue of their difference in specific gravity. The gas after this treatment still contains a certain amount of tar in the shape of a fog or mist, and this is usually removed by friction in some sort of mechanical extractor.

These accepted methods of tar removal are now being replaced by others of greater value, such as the electric de-tarring system, in which the gas is sent through an electric field, the action of which is to cause the tar to coalesce and drop out of the gas, and the system which embraces progressive washing combined with progressive cooling, in which, due to the fact that the gas is not cooled below the point where any volatile hydrocarbons are condensed or absorbed by the effluent, the tar is fractionated into pitch, heavy oils and middle or light oils, without the usual interposition of a tar still.

Tar is one of the most valuable of all coal-gas residuals, and while in this country, owing to economic conditions, it has found quite some extended use in its original form, it finds its greatest value in its application in the arts; the distillation of tar at certain temperatures produces a water-like oil, which in turn forms the base of so many of the beautiful coal-tar colors so much in demand at the present. Carboic acid, naphthalene, anthracene and benzol are also produced by this distilling process, and each of these constituents in turn produces a long series of other products.

Naphthalene

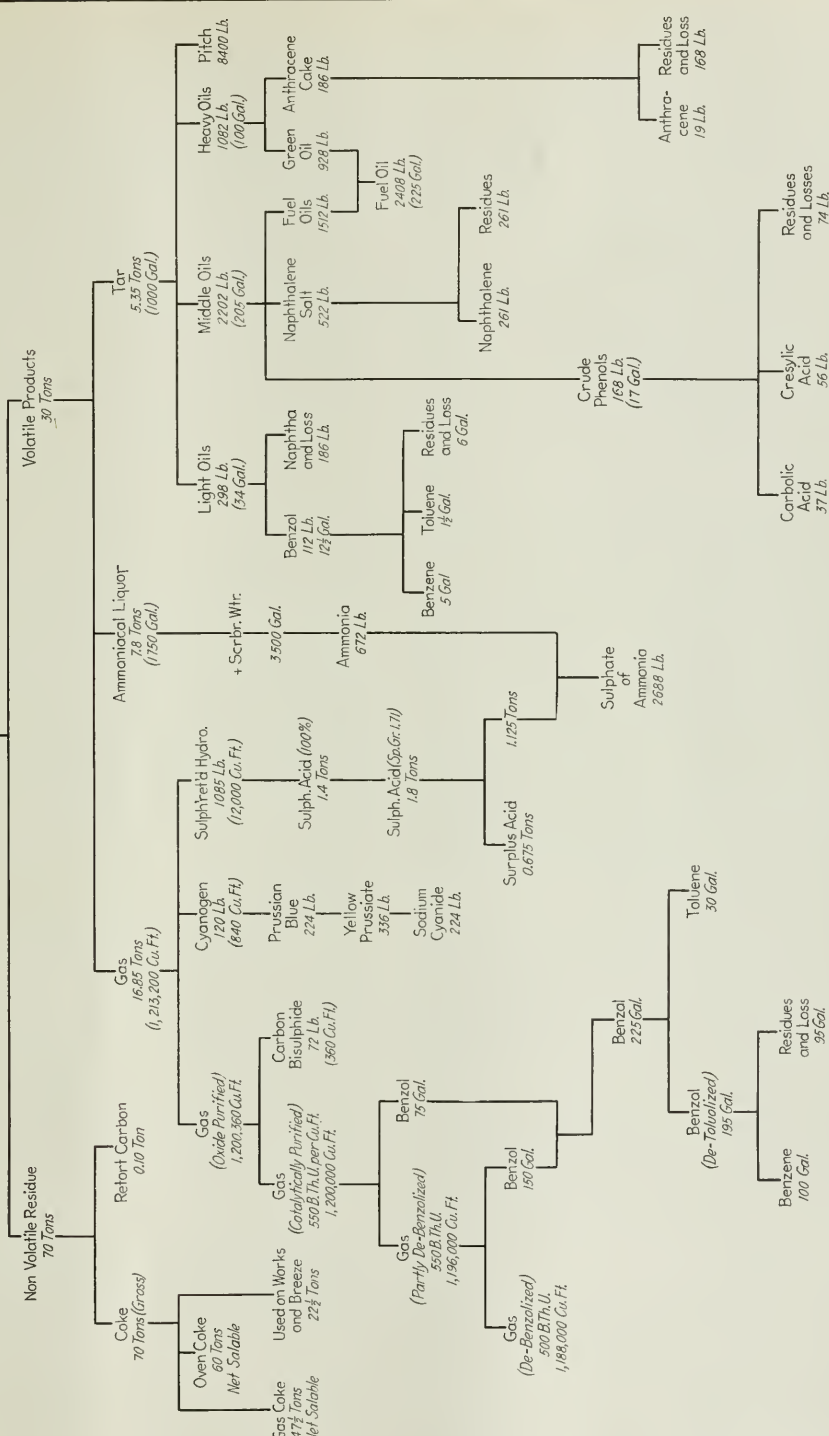
Naphthalene is one of the gas constituents which accounts for a great deal of the trouble experienced in present-day methods of carbonization, but its removal can be accomplished by washing the gas with a suitable oil, such as anthracene or creosote oil, or water-gas tar, the resultant emulsion being gradually cooled, thus causing a separation of the naphthalene crystals.

The formation of naphthalene is probably due to the high heats employed in present-day carbonization, it being a generally-accepted fact that this formation is brought about by a partial decomposition of the tar in the gas. Fortunately, the greater portion of the naphthalene produced goes over into the tar effluent and is thus removed with the latter, as its excessive presence in the apparatus and gas mains usually causes a stoppage. Naphthalene is also due to the character of the coal used and upon the time of contact between the gas and the hot coke and hot retort walls. Besides other domestic uses, naphthalene is of great importance at present in the production of dyes.

Cyanogen

Cyanogen is a carbon-nitrogen compound, and it is probably produced during the period of carbonization in the form of hydrocyanic acid by the decomposition of some of the ammonia due to the contact of the gas with hot coke and the hot retort walls, this statement being substantiated by the fact that the quantity of cyanogen produced by the carbonization of any particular coal bears a certain relation to the amount of nitrogen (ammonia-producing agent) in the coal.

PRODUCTS FROM THE DISTILLATION OF 100 TONS OF BITUMINOUS COAL

COAL
100 Tons

In its gaseous form cyanogen is colorless and very poisonous; in combination with potassium it forms potassium cyanide, this latter compound having found its largest application in the cyanide process of gold extraction, which process depends upon the solubility of gold in a dilute solution of potassium cyanide in the presence of air or some other oxidizing agent; this process is best adapted for use with free-milling ores after the greater portion of the gold has been removed by amalgamation, thus recovering such portions as were not taken up by the amalgam, the gold being later usually separated from the cyanide solution by an electric or metallic precipitation process.

Potassium ferrocyanide is the base of a great many cyanogen products, one of the principal products being Prussian blue; this coloring matter is obtained by mixing the potassium ferrocyanide with a solution of ferrous sulphate, a grayish-white precipitate of ferropotassic-ferrocyanide resulting, the mother liquor, which contains potassium sulphate, being removed from the precipitate by decantation. After this precipitate has been allowed to settle, it is washed with a large amount of water and then oxidized, this oxidation giving it the beautiful blue color required in the dyeing industry.

In one process covering the removal of cyanogen from gas, iron sulphate, commonly known as copperas, and ammonia are used as the two reagents necessary to combine with the cyanogen, and a certain portion of the ammonia thus removed from the gas remains in the cyanide cake, the final resulting compound being ammonium ferrous-ferrocyanide. This process, therefore, requires that the cyanogen be removed before the ammonia has been extracted, but in another process the ammonia is replaced by milk of lime, and consequently follows behind the ammonia extraction process, the final product being calcium ferrocyanide.

In another process used in England the cyanogen is removed from the gas by washing the latter with a solution of soda and ferrous carbonate, the resultant liquor being deprived of its ammonia by evaporation. This liquor is then pumped through a press where the insoluble matter is removed, the cleared solution being then crystallized, giving sodium ferrocyanide, or prussiate of soda. This latter product is washed for purification and then recrystallized.

Ammonia

Ammonia is a nitrogen-hydrogen compound, and besides being a source of great revenue to the coal-gas producer, its removal from the gas is necessary for both practical and hygienic reasons; its presence in the gas exercises a destructive influence on the brass and copper work of meters and gas fittings, and when burned in conjunction with gas it gives off noxious fumes of oxides of nitrogen.

The usual method employed for the removal of ammonia depends upon the solubility of ammonia in water, as at ordinary temperatures water can absorb about 708 times its volume of ammonia gas. Raw ammonia liquor from a gas works usually contains from one to two per cent of ammonia, and owing to the excessive cost of transporting this weak liquor it is usually worked up into concentrated liquor, aqua ammonia, or ammonium sulphate.

Concentrated ammonia is a product obtained by distillation of the raw liquor with lime, and absorption, in water, of ammonia evolved. It is used in the production of other ammonia compounds.

Aqua ammonia is a solution of ammonia in distilled water, a great deal of it, in a dilute solution, being used for cleansing purposes.

Ammonium sulphate is produced by distilling the liquor and absorbing the ammonia vapors in a sulphuric

acid bath, thus forming the sulphate crystals; or it may be made by passing the gas, after the tar has been removed, directly through the acid bath, this being the so-called direct process. The only really direct process, however, is the one in which the ammonia in the gas is combined directly with the sulphur radical, the latter also existing in the gas, this compound being later oxidized. This process requires that the gas be washed with ammonium polythionate, the latter absorbing both ammonia and hydrogen sulphate, the resultant liquor being oxidized or regenerated by means of sulphur dioxide gas, and after the liquor contains about 35 to 40 per cent of ammonium sulphate in solution it is boiled, resulting in the breaking down of the polythionates with the consequent precipitation of the sulphur; this sulphur is returned to the sulphur stoves for the further production of sulphur dioxide, while the cleared liquor is evaporated to crystallization, this method of procedure therefore requiring no sulphuric acid for the production of the salts, but finding all of the necessary reagents in the gas itself. Sulphate finds its greatest use in the manufacture of fertilizer, it being the active nitrogen-carrying agent in this product; it is also used for the production of other ammonia compounds.

Ammonium chloride, commonly termed sal ammoniac, is produced by using hydrochloric acid as an absorbing agent, followed by evaporation and crystallization. Ammonium sulphate is the principal source of sal ammoniac production in this country, the sulphate being heated in conjunction with common salt for its formation. Sal ammoniac is used as an agent in the galvanizing process, for soldering and as an agent in electric batteries.

Liquid anhydrous ammonia is produced by freeing the ammonia gas of all moisture and impurities, after which it is liquefied under pressure. This product is used in the production of low temperatures by the absorption of heat, as in refrigeration.

Ammonium carbonate is produced by heating ammonium sulphate in conjunction with calcium carbonate, and it finds its greatest application in the scouring of wool.

Ammonium nitrate is produced by neutralizing nitric acid with ammonia, and it is used in the manufacture of explosives.

There are many other ammonia compounds, but the ones here cited are the principal products, and they can all be prepared from ammonium sulphate, thus making this latter compound one of the principal by-products of coal distillation.

Benzol and its homologues are obtained during the process of tar distillation and from the products due to coke-oven distillation, they being secured in the latter case by washing the gas with a suitable oil, the resultant product being purified by repeated distillation and washing, thus separating it into benzol, toluol, xylo and solvent naphtha. The greatest usefulness of these products is in the production of dyes, explosives, artificial perfumes and pharmaceutical compounds.

Coal-Tar and Benzol Products

A large number of our industries are dependent upon the use of coal-gas by-products for their successful operation, as is witnessed by the following statement, taken from the census of 1909. The principal industries dependent upon coal-tar products, with the number of employees, capital invested and annual value of product are:

Industry	Employees	Capital	Product
Textile	916,000	\$1,841,000,000	\$1,685,000,000
Leather	62,000	323,000,000	328,000,000
Paper	81,000	400,000,000	260,000,000
Paints and colors.	30,000	250,000,000	

Thus we find a total of 1,089,000 persons employed in these four industries, with a capital investment of \$2,814,000,000, and an annual product for the first three representing \$2,273,000,000 in value. Since the 1909 census these industries have all increased their production, and when taken in conjunction with other manufacturers, such as the producers of shoe dressings, writing and printing inks, etc., it is perhaps safe to estimate that at present fully 2,000,000 persons find employment in industries which are dependent upon dyestuffs for their success.

Artificial dyestuffs produced from the by-products of coal distillation have practically displaced those formerly used, such as natural indigo, cochineal, fustic, madder and many others, and this is properly so, because the artificial material is easier applied, has a greater brilliancy of color and can be secured in a great variety of shades; but, unfortunately, our American industries have always depended on Europe to supply the necessary material. Statistics teach us that 80 per cent of our coal-tar dye requirements are imported from Europe, principally from Germany, the other 20 per cent being produced by American manufacturers. But here again we find that we must turn to Europe for our supply of the greater portion of the necessary intermediates, or raw product, before we can produce this 20 per cent of coloring matter.

The present war soon brought about an acute situation among our manufacturers, as the stock on hand was soon depleted, and a replenishment became almost impossible. The seriousness of this situation can readily be recognized when I mention that "sulphur black" increased in price from 20 cents to as much as \$3 per pound, indigo from 15 cents to \$1 per pound, paranitraline from 15 cents to \$1.75, aniline oil from 10 cents to \$1.75, betanaphthol from 12 cents to \$1.50 and so on through the list. As regards the raw or primary material, I might mention that the price of benzol has increased from 20 cents to as much as \$1.20 per gallon, with about 70 cents as a contract price, while toluol has increased from 25 cents to about \$6 per gallon, with a contract price of about \$4.25.

These conditions certainly compel us to turn seriously toward our own supply of tar and benzol and cause us to question ourselves as to our ability to do that which we have permitted others to do for us. Several American manufacturers have gone ahead vigorously in an attempt to supply our domestic needs, and credit for stepping into this breach must be accorded such firms as the Shoellkopf Aniline and Chemical Works, Inc., Buffalo, N. Y.; the Hudson River Aniline Color Works, Albany, N. Y.; W. Becker's Aniline and Chemical Works, Brooklyn, N. Y.; Central Dyestuff and Chemical Company, Newark, N. J., and Heller & Merz Company, Newark, N. J.

Other concerns have taken up the manufacture of intermediate products from our raw material, and while all of these manufacturers are being supported by the allied industries to-day, the question as to their future is still an open one, and reference to this will be made later.

We have the necessary raw material, tar and benzol, on hand, and a lack of these products will soon bring about their further recovery if the situation should demand it, as the great amount of coal carbonized for the production of coke in America, as previously stated, is still produced in the wasteful bee-hive oven. Economic and commercial conditions have prevented the development of the dye and other allied industries in this country, and consequently our manufacturers have in the past diverted their raw material in great measure into the production of tar oils and pitches.

Tar is a very complex substance, and it has been estimated that it consists of a mixture in excess of two hundred chemical compounds. The constituents of tar are usually divided into three classes, the first being the hydrocarbons, the second the phenols and the third the nitrogenous compounds, these classifications being made in accordance with the chemical reactions of the compound in question. The hydrocarbons, as can be seen from the name, are composed of hydrogen and carbon, and they are termed chemically indifferent substances because they exhibit neither alkaline nor acid properties. The hydrocarbon compounds, of which benzene, toluene, xylene, naphthalene and anthracene are the most valuable, form the principal portion of coal-tar. The phenols, or the second class of constituents, consist of oxygenated bodies of carbon, hydrogen and oxygen, being known as the "tar acids." Owing to their weakly acid condition they can be dissolved in caustic alkali solutions, but not in dilute acids. The most important members of the phenol group are carbolic acid and cresol. In the third class we find compounds composed of carbon, hydrogen and nitrogen, these compounds being of a basic nature and soluble in acids.

The distillation of coal-tar thus serves to produce a number of fractions, and these fractions in turn form the base for manufacturing various other important products. Distillation of the average coal-tar usually gives us four fractions, the first being "light oil," which comes over at a temperature of between 70 deg. and 160 deg. C. (158 deg. and 320 deg. Fahr.); the second is a "middle" or "dead oil," coming over between 160 deg. C. and 230 deg. C. (320 deg. and 446 deg. Fahr.); the third is a "heavy oil," including anthracene oil, and it comes over at between 230 deg. and 360 deg. C. (446 deg. and 680 deg. Fahr.), while the fourth is pitch, or the residue above 360 deg. C.

The first fraction, or "light oil," produces such intermediate products as benzene, toluene, xylene and phenol (carbolic acid), while the crude commercial products are benzol and solvent naphtha; the intermediate chemical products are nitrobenzene, aniline salts and oils and carbolic acid, while the refined chemical products are the nitrotoluenes, diphenylamine, dyes, hydroquinone and various medicines and drugs.

The "middle oil" gives us phenol, creosols, naphthalene and heavy hydrocarbons as an intermediate product, the crude commercial products being creosote oil, lampblack and various disinfectants. The intermediate chemical products are carbolic acid, picric acid, phthalic acid, naphthols, naphthylamine and salicylic acid, while the refined chemical products consist of picric acid, the picrates and several other nitro-compounds used in the manufacture of explosives; naphthol dyes, colors, indigo and refined carbolic acid.

The "heavy oils" produce creosols, naphthalene, anthracene, heavy hydrocarbons and quinoline bases; the crude commercial products consist of oils used in road making, lampblack, creosote oil, roofing and paving tars. The intermediate chemical products consist of anthraquinone and alizarin, while the alizarin dyes are known as the refined chemical products.

The fourth fraction consists of soft and hard pitch, a large portion of which is used in the manufacture of aniline dyes, necessitating quite a number of very complicated chemical combinations, and the chief sources of this product are to be found in benzene, toluene and phenol or in the nitro-substitution products of these compounds. This material is used in conjunction with nitric, sulphuric and acetic acids, alcohol, sodium nitrate, caustic alkalies, zinc dust, bromine and chlorine.

The naphthol dyes are produced from phthalic acid,

the naphthols and naphthylamines, etc., these being intermediate products derived from naphthalene. The eosin dyes are due to benzene and naphthalene through the medium of resorcin and phthalic acid. Indigo is also a naphthalene product.

Anthracene is converted into anthraquinone by oxidation, and this in turn gives us the hydroxanthraquinones and such derivatives as the alizarins, purpurin, etc., all of which are used in the production of alizarin dyes.

Carbolic acid, or pure phenol, is, as stated before, obtained from both the light and middle oils, and it can also be made synthetically from benzene. It is used as a drug as well as an antiseptic and it occupies a very important role in the manufacture of picric acid and some of the dyes.

The manufacture of synthetic phenol, using benzol as a base, was not encouraged or practised in this country before the present war, and consequently little attention has been paid to this branch of conservation, and it may therefore be interesting to give a short explanation of its manufacture.

The benzol stripped from the gas, or secured as a distillation product from tar, is first sulphonated by mixing about 2.7 parts of 98 per cent sulphuric acid with one part of benzol in a cast-iron vessel having a capacity of approximately 400 gal., this vessel being supplied with means for both heating and cooling the liquid, the escaping matter passing through a reflex cooler, about 150 pounds of benzol being treated at a time. This mixing vessel is provided with an agitating device, and the agitator is set in motion as soon as the benzol is admitted, the sulphuric acid being in the mixer before the benzol is added.

As soon as these two liquids mix, the temperature rises to between 62° and 68° C. (144° and 154° Fahr.), and when the chemical reaction produces no further increase, external heat is applied to a point corresponding to the boiling point of benzol, about 88° C., or 190° Fahr. This sulphonation process is usually completed in from seven to eight hours.

The sulphonic acid produced as per the above is run into a neutralizing vessel, the latter having a lead lining, where it is first neutralized with milk of lime and then treated with waste calcium carbonate. This treatment is liable to thicken the liquor, and some water is added to thin it out, after which the mixture is subjected to a boiling temperature for about one-half hour, steam being used for this purpose. After the steam has been turned off a volume of water amounting to 150 per cent of the volume of the original sulphonation mixture is added, this being necessary in order to prepare the calcium sulphate for washing and filtration.

This mixture is now forced through a filter press, where it is also washed with water, the latter amounting to about 50 per cent of the volume of the mixture. The resultant product is a calcium benzene-sulphonate mixture, and this is now treated with solid sodium carbonate in order that it may be converted into a sodium salt, while the precipitated calcium carbonate is used in neutralizing the sulphonation mixture. The sodium benzene-sulphonate solution is now evaporated, the resultant salt being dried and pulverized, this dried product being placed in a fusion vessel where about 500 lb. of caustic soda are melted with about 50 lb. of water for every 600 lb. of the dry sodium benzene sulphonate, the caustic soda and water being heated to about 270 deg. C. (518 deg. Fahr.) before the sodium benzene-sulphonate is added; heating is continued up to about 315 deg. C. (600 deg. Fahr.), a still further, but slight, rise in temperature taking place after the heat is turned off, the operation being considered complete when all of the sodium salt has been dissolved and the mixture is thin.

The resultant product is now removed from the fusion vessel by means of ladles and placed on shallow trays, where it is allowed to cool, after which it is crushed and dissolved in water, being then treated with sulphuric acid until sulphurous acid begins to go off, this sulphurous acid being finally blown out of the vessel with an air blast, thus separating the crude phenol from the mixture, the latter being then distilled, and the phenol crystals recovered by crystallization. The phenol crystals obtained in this manner usually contain some sulphur compounds which produce disagreeable odors, but this can be removed by distilling the crude product in conjunction with animal charcoal.

The light oil fraction is also responsible for the production of photographic developers as well as of such drugs as phenacetin, acetanilide, antipyrine, aspirin, saccharine, and phenolphthalein.

The synthetic production of many perfumes also owed its existence to coal-gas tar, and it is almost impossible for the layman to differentiate between the natural products and the synthetic substitutes.

Modern coal-tar dye classification divides this product into eight classes, or

- 1—Acid dyes;
- 2—Tannin dyes;
- 3—Dye salts;
- 4—Sulphur dyes;
- 5—Vat dyes;
- 6—Mordant dyes;
- 7—Developing dyes;
- 8—Albumin dyes;

and they may be described as follows:

1. The greater portion of the acid dyes consist of sodium salts of sulphonic acids, organic acids, or nitric acids, and they are represented by the azo dyes, the eosines, and picric acid. They are used principally for dyeing wool and silk, this material being dyed directly with the aid of an acid or an acid salt in the bath. Cotton is not dyed by these compounds.

2. The tannin dyes are also classed as basic dyes, consisting in large part of hydrochloric acid salts of color bases; if cotton is first treated with tannin we find that it is easily dyed, but we find that wool and silk can be dyed directly without the aid of this intermediate treatment.

3. The dye salts receive their names from the neutral or alkaline salts which are dissolved in the dye solution; they are also termed direct-cotton dyes and substantive cotton dyes, consisting usually of sodium salts of sulphonic or organic acids, the cotton fibre taking them up in this state. The dye-bath also receives some common salt or Glauber salt.

4. The sulphur dyes consist of a class of colors which are very popular owing to their cheapness and fast qualities. The bath is made alkaline with the soluble sulphides, the color being later developed by oxidation after the cotton material has been removed from the bath.

5. The vat dyes show but little attraction for the common fibers, and they are fixed on the material by reducing them to their leuco compounds in the vat. The material to be dyed is immersed in this reduced dye and thus becomes saturated with it, after which it is exposed to the air, where the color is developed by oxidation.

6. The mordant dyes are of a weak acid character. In order to cause their retention by the fiber, they must be converted into color lakes by means of a mordant, with which the fabric is impregnated prior to treatment in the dye bath. The color known as Turkey red is an ex-

ample of this class of dye, being made from alizarin, which is yellow and is almost insoluble; the cotton fabric to be dyed is first treated with aluminium salts and Turkey red oil, then is boiled in the alizarin, after which it is treated with calcium salt, the Turkey red color resulting.

7. The developing dyes, owing to their insolubility, cannot be applied directly to the fabric to be dyed, but they are produced upon the fabric itself by first saturating the latter with one soluble component and then immersing it in a second bath of another soluble component, these two components uniting and forming an insoluble dyestuff.

8. The albumin dyes will not adhere of themselves, and they require that the fabric be first treated with some strongly adhesive substance, the principal substance used for this purpose being albumin.

This classification of dyes is only mentioned in order to make somewhat clearer the complex nature of the dyer's art.

The coal-tar dyestuffs found their origin in England, where, in 1856, W. H. Perkin discovered mauve, a sort of violet; this was an accidental discovery, as Perkin was seeking something entirely different, but his chemical ability, combined with a keen business sense, caused him to persevere in this line of chemical research, and he lived long enough to find his crude beginning develop into an immense business which utilized a material, coal-tar, that had previously been considered worthless. The discovery of mauve was soon followed by magenta and fuchsins, while the soluble blues were discovered in 1862, Hofmann's violet and Bismarck brown in 1863, naphthol or Martius yellow in 1864, and the nigrosines in 1867.

These beginning soon drew the attention of the Germans to this new industry, and, recognizing the immense possibilities in its development, they very quickly applied their usual patient perseverance and intelligent research to the advancement of this new art; this resulted in the production of orange red, malachite green, chrysodine, scarlet, metanil yellow, methylene blue, and the eosines between 1875 and 1878; auramine was first produced in 1883; tartarazine and benzopurpurine in 1884; Congo red, benzoazurine in 1887. The early nineties saw the discovery of direct black for dyeing cotton, and acid and chrome black for dyeing wool. It was von Bayer who first succeeded in producing indigo, but many years of patient labor was required before a practical synthetic process permitted of placing this important dyestuff on the market in a commercial sense.

From the latest reports, I learn that the Dow Chemical Company of Midland, Mich., is erecting, or has erected a plant for the production of 5000 lb. of 20 per cent indigo paste per day.

Realizing that industrial progress in this line meant commercial supremacy, the Germans quickly learned that success meant patient scientific research, combined with an adequate supply of raw material, with the result that by-product coke ovens were soon established in the immediate vicinity of their blast furnaces, where the distillation of the coal for the production of the necessary metallurgical coke soon supplied them with all of the by-products required in the development of this new art, an example which we might have followed in the past with great profit, and with relief of mind at present.

The cost of producing dyes in this country is said to be 44 per cent greater than in Germany, as it is estimated that the cost of a plant capable of producing 3,000,000 lb. of dyestuff per year would be \$104,000 in the United States and \$70,000 in Germany, while the labor required would amount to \$116,236 in the United States

and \$61,493 in Germany. The cost of material would be \$443,000 in the United States and \$317,000 in Germany. These comparative figures show a vast difference in favor of Germany, and the successful establishment of this industry in our country would require that protection in some form be given the American manufacturer in order to make up this discrepancy.

The discrepancy is even greater than these figures would seem to indicate, because the German manufacturer has been in the habit of selling his surplus production, and that at a figure lower than the one paid by the domestic consumer. The establishment of this industry in the United States means opposition to the preeminent position of the Germans, whose success is based on a solid foundation of 30 years' standing, and which, therefore, becomes a standing challenge to our chemists and capitalists. We have the necessary raw material, and we possess constructive engineering ability of a character which can supply all of the needful apparatus, but, with all this, an almost unlimited capital and patience will be required.

But this is not all that is required, as chemists, trained in this particular work, are not numerous in this country, and their necessity is shown when it is mentioned that in one German works, producing about 500 colors, we find 300 chemists employed; of these about 100 are engaged in analytical work, and the other 200 are in charge of the actual manufacture of the dyes, thus placing the production of only two or three colors under any one chemist.

After the capital has been supplied, and this new industry has been properly started, it will be necessary to secure proper legislation prohibiting "dumping" on our shores, a performance heretofore practised by the Germans, as well as a prohibition against an unfair restraint of our trade due to the arbitrary action of the German monopoly which is now allowed by foreign law, but not permitted by our own. Any scheme entered into must therefore necessarily depend upon an effective law which will prevent the control of our markets by foreign monopolies in the same manner as a domestic monopoly is now prohibited.

Advices received from Germany indicate that the German monopoly will re-enter the American market as soon as the war is over, and that it will make tremendous efforts to regain this lost business, being prepared to make extraordinary concessions in order to take the business from its infant competitors. It therefore is required of us that we place this new industry on a firm foundation as soon as possible, and that we seek such Federal legislation as will permit the continuance of the project without financial loss.

The dyestuffs subject could be treated at greater length, but the explosives, due to coal-gas residuals, also claim some little attention. The picric acid produced from carbolic acid, or phenol, is the base of "lyddite," used by Great Britain; of "melinite," used by France, and of "shimose" powder, used by Japan; but toluene, a tar or benzol product, is responsible for the production of the new explosive, "trinitrotoluene," commonly known as "T. N. T.," so much used in the present war.

Both picric acid and "T. N. T." are manufactured by a sulphonating and nitrating process, the method of operation in both cases being somewhat similar in detail. Phenol is produced by permitting that fraction of tar distillation coming over at a temperature between 150 deg. and 230 deg. C. (302 deg. and 446 deg. Fahr.) to stand and cool until the naphthalene crystallizes out, after which the mother liquor is agitated in the presence of a solution of caustic soda, the latter combining with the phenol and forming sodium phenolate. This sodium phenolate, due to its weight, sinks to the bottom of the

mixing chamber, whence it is drawn off and treated with sulphuric acid, this latter treatment setting free the phenol. This compound is now run into a still and fractionated, the phenol coming over at a temperature between 180 deg. and 190 deg. C. (356 deg. and 374 deg. Fahr.) and crystallizing in sharp, needle-like crystals from the distillate. An equivalent weight of concentrated sulphuric acid is now mixed with the phenol, and the mixture is heated in an iron vessel by means of a steam coil to a temperature of slightly above 100 deg. C. (212 deg. Fahr.). The mixture is next allowed to cool slowly, after which it is dissolved in twice its weight of water, and then slowly added to three times its weight of nitric acid, the nitration being completed by heating with steam after all fuming has ceased. This final mixture is now allowed to slowly cool down, thus permitting the picric acid to crystallize out, after which it is purified by washing with warm water, and then recrystallized.

This explosive, due to its acid nature, combines with metals, and thereby forms picrates, the latter in some instances being much more sensitive to percussion and friction than picric acid itself; this is a serious drawback, as it renders the shell containing this compound subject to explosion while in storage or during transportation, by heavy jolting. This, as well as many other disadvantages, caused the explosives manufacturers to turn their attention to another source, and they finally evolved the present-day trinitrotoluene. This compound is made by first converting the toluene into a mononitro compound, after which it is treated with nitric acid at a slight increase in temperature, this converting the mononitro compound into dinitrotoluene, after which the latter is nitrated in a sulphuric acid solution with concentrate nitric acid, the final product thus formed being trinitrotoluene. This compound is also produced from orthonitrotoluene by means of a sulphonating process similar to that used in the production of picric acid, after which it is nitrated and the resultant crystals are then purified in alcohol, being recrystallized and the alcohol removed in a centrifugal hydro-extractor.

In these statements I have tried to explain the wonderful properties possessed by a by-product which some years ago was considered a waste, and I trust my words will assist in calling your lasting attention to the possibilities of creating and maintaining an industry which can only redound to our credit and which will certainly add to our national wealth by not only conserving a vast amount of fuel, but which will also retain in our country a large sum of money which is annually expended in the purchase of materials which should be manufactured in the United States.

Baltimore, Md.

Potash Production in United States in 1915.—According to a United States Geological Survey report by W. C. Phalen, the production of potash in this country in 1915 was valued at about \$350,000. The quantity represented, however, is very small and hardly enough for a week's normal consumption. Potash was recovered as a by-product in cement manufacture at Riverside, Cal., from alunite in Utah, from certain Western alkaline lakes, and from kelp along the Pacific Coast.

The Minnesota Testing Laboratories, Inc., has recently been organized, and will be a consolidation of several interests, including the firm of Crowell & Murray, Lerch Brothers, and the Duluth Testing Laboratory. The officers of the new company are Benedict Crowell, president; Fred Lerch, vice-president; C. A. Graves, secretary-treasurer, and K. M. Way, manager.

Society of Chemical Industry

New York Section Meeting.

The meeting of the New York Section of the Society of Chemical Industry, held on the evening of Friday, April 21, in Rumford Hall, Chemists' Club, proved very interesting, being devoted to three papers of very different character, but all of them very instructive.

The chairman of the section, Dr. W. M. Grosvenor, presided.

The Application of Centrifugal Force to Suspensions and Emulsions

Mr. Eugene E. Ayres, Jr., of the Sharples Specialty Company, West Chester, Pa., presented a paper on the application of centrifugal force to suspensions and emulsions, giving in the introduction a sketch of the principles of the design of the Sharples centrifuge.

Mr. Ayres pointed out that during the last century centrifugal force has been applied in a variety of useful fields. Centrifugal pumps, fans, filters, and hydro-extractors are known everywhere. It is not strange that the application that should eventually prove of the greatest value should have been developed more recently than all the rest. The principle of separation by differentiation of mass and of velocity of motion is even yet only meagerly understood.

It is a fallacy to think that if the driving power of a centrifuge is gradually increased, the speed increases continually. This is not so as in practice a point will at last be reached when an increase in driving power is accompanied no longer by an increase in speed. This is due to lack of an absolutely perfect "balance." If the center of gravity does not coincide with the axis of rotation, the rotating element will be subject to more or less severe lateral vibration, and may even tend to change the direction of the axis of rotation. As long as these disturbing effects are produced the speed cannot increase.

In practice "balance" is only a relative term. A high-speed bowl should be as nearly "in balance" as is humanly possible, and the inevitable error must be automatically neutralized in some such manner as to entirely eliminate vibration. Recently, big strides have been taken toward this ideal, and an immensely higher centrifugal force is possible to-day than was even contemplated a few years ago.

Another fundamental principle to be observed in the manufacture of high-speed centrifugals is that high peripheral speed and large diameter are wholly subordinate to the number of revolutions per minute. This may be clearly seen from the formula for centrifugal force, which equals 0.0003410 times the radius in feet times the weight in pounds times the square of the number of revolutions per minute.

In this connection it is interesting to compare a modern centrifuge, whose internal diameter is 1½ in., with our own earth, whose diameter is nearly 8000 miles. The peripheral speed of the earth is more than four times that of the little bowl, but its centrifugal force is only about one fifteen millionth as great. But the earth makes one revolution in twenty-four hours, while the little bowl turns 700 times every second.

Our experimental procedure has generally been as follows: About one liter of solution was poured into the bowl of a little centrifuge revolving 700 times a second and exerting a peripheral force 40,000 times gravity. The solution was passed in at a known rate and remained under the influence of the force for a period of time; that, of course, depended upon the measured rate of supply. The discharge began only after 250 c.c. had been supplied. When the rate of flow was 100 c.c. per minute, each c.c. of liquid therefore remained in the bowl 2½ min. The internal diameter of the revolving bowl was 1½ in. The total depth of the layer of liquid was ½ in. The average distance the particles had to move before coming in contact with the periphery of the bowl was therefore ¼ in. If two liquids were to be separated, the average distance traversed by either liquid varied from nearly zero to nearly ¼ in., depending upon the relative percentages of the liquids.

The extreme importance of this dimensional data will

be fully realized after consideration of the following theoretical treatment:

A disperse phase, whether solid or liquid, will move through its dispersion medium at a velocity that must depend upon all of the following factors in greater or less degree:

1. Centrifugal force exerted.
2. Viscosity of the dispersion medium.
3. Temperature of the dispersion medium.
4. Difference in specific gravity of disperse phase and dispersion medium.
5. Relation between the mass and the surface area of the particles.

6. Chemical nature of the continuous and disperse phases.

The distance the particle will travel in a given period of time will, of course, depend on this velocity of motion. The small diameter of our bowl means three things: A short distance for the particle to travel, the possibility of safely generating a great centrifugal force, and a consequent reduction of time necessary to move the particle a given distance.

The convection currents caused by difference in temperature are greatly increased in volume and velocity by centrifugal force. The apparatus must, therefore, never be warmer than the liquid. Any slightest tremor or vibration in the rapidly revolving bowl must inevitably cause a disturbance to interfere with the motion of small particles.

Temperature and viscosity, although relative functions, are apparently independent in their effect upon the velocity at which a particle can be moved. As long as the viscosity of a liquid is greatly reduced, by a comparatively slight increase of temperature, the velocity of particles is increased by rise of temperature. This effect is seen very strikingly in the case of highly viscous lubricating oils. But there are strong indications that for some liquids, or perhaps at some point for every liquid, an increase of temperature will diminish the velocity imparted by centrifugal force. This statement seems to be especially true of melted waxes or fats where the viscosity is not so decidedly affected by temperature. . . . Practical oil men have found that a low temperature is sometimes advantageous for gravity settling of certain emulsions, a most natural result in view of the effect of heat to increase the solubility of a solute to subdivide a colloid. The fact that this phenomenon is so infrequently observed is, in our opinion, due to the very great part viscosity usually plays in centrifugal separation.

The difference in specific gravity naturally exerts an important influence on the separation of a particle from a liquid, but this effect is relatively diminished where the size of the particle has been reduced beyond a certain point. But even for particles that are large enough for microscopic observation, the difference in specific gravity is often overshadowed by some of the other factors, because in the little centrifuge, although a very small difference is magnified 40,000 times, often a heavy particle will move more slowly than a light one.

The sixth factor, the function of chemical composition, brings up a most interesting question, one that we feel has not been conclusively demonstrated by our own experiments. If we are given three liquids—one an oil, another an aqueous solution of an electrolyte, the third an alcoholic solution of a carbohydrate, each liquid having the same specific gravity, the same viscosity, and handled at the same temperature, will the velocities of identical particles be the same? We believe not. Further on a number of special cases will be cited in support of our assumption.

We have not mentioned osmotic pressure as a factor affecting centrifugal separation for the reason that our discussion does not relate to true solutions. Colloidal solutions have very small osmotic pressures, and the comparatively crude emulsions and suspensions with which we have most to do have none.

It should be clear that once the considerable mechanical difficulties of generating a great centrifugal force have been overcome, and the general principles of centrifugal separation are understood, the science of its application to suspensions and emulsions is for the most part related directly to the science of the suspensions and emulsions themselves.

Every chemist knows the effect of various reagents to "precipitate" a colloid. By precipitation is meant the bringing together of the fine particles to form larger particles that will eventually settle by gravity. The larger particles have no greater specific gravity than the colloids, but their surface area has decreased with respect to their mass, and the effect may be roughly compared to the formation of rain-drops from the cloud. The reagents and conditions that increase the size of the particles of the disperse phase

will naturally make centrifugal separation much easier. From a commercial point of view it is usually practicable to "break" an emulsions in this way with only a trace of reagent. A trace is nearly always sufficient to increase the particle to the micron stage, but a comparatively large excess of reagent is required to still further affect the precipitation, for emulsions and suspensions are much less sensitive to electrolytes and other precipitating agents than emulsoids or suspensoids.

The point we are trying to make is this: For a practical separation of the amicon the centrifuge must be applied when the particle is still so small as to be just visible under the microscope. As a matter of fact, even here a very great centrifugal force is necessary to bring the rate of flow up to a point at which the liquid can be profitably handled, but the modern commercial centrifuge is fully equal to the problem. We are speaking now of the emulsion or suspension obtained from the pure colloidal condition. A little further on we wish to take up the types more frequently met with in practice, where the colloidal characteristics may be fully as marked, but where the "emulsifying agent," or some other peculiar condition, plays a great part.

As a matter of convenience we shall here call attention to the fact that electrolytes are not always the only or the best precipitating agents. Centrifugal separation of some colloids is greatly expedited by a trace of some other colloid, such as, for instance, albumen. A patent was recently gotten out for the acceleration of gravity settling by the addition of a trace of formaldehyde. Unfortunately we have not yet come across the emulsion that will separate by this means. An old and effective expedient has been the addition of some inert substance to absorb water. A recent process for cotton seed oil soap emulsions is based on this principle. There is a certain organic liquid emulsified with mixed acid whose separation is greatly accelerated by the addition of two reagents which act together with the acid to form minute bubbles of gas. As one of the reagents is itself a colloid, it is hard to determine the correct theory. This same emulsion can also be broken by a mild electrolysis. The effect of bubbles of gas or of electrolysis on centrifugal separation has not yet been noted.

A very peculiar phenomenon is the effect of a continuous mechanical vibration or jarring. Certain emulsions have been broken by attaching an electric vibrator to the tank, and we have had instances where an apparently hopeless emulsion has broken by a long journey in an express train.

In practice difficult suspensoids are being agglomerated in a variety of ways, perhaps the most interesting of which has been a change in the vapor tension of the liquid by applying pressure or vacuum.

All these procedures represent mere gropings after the fundamental laws of colloidal and physical chemistry.

Practical men are now studying the emulsion as a function of surface tension, and we hope that their very interesting results will be made public. We are probably hoping too much.

A few of the methods of increasing the size of a colloidal particle have been mentioned. Concentration and heat should be added to the list. Occasionally we meet with cases that can be handled commercially by centrifugal force only after being maintained at an elevated temperature for several hours. A gradual concentration by spontaneous evaporation will sometimes change an amicon to a submicron, but what should we expect from an instantaneous increase in concentration such as can be secured from a continuous centrifuge? Unless precautions are taken to avoid this effect, the liquid is delivered from the continuous centrifuge in a tiny stream at a velocity exceeding three miles a minute, and striking the walls of the covers are immediately broken into infinitesimal particles. The resultant sudden volatilization can be easily stopped by arranging a circulation of a limited volume of saturated air through the covers and the receiving vessel, but there seems to be no way of avoiding the mechanical impact in a machine of this type.

Fortunately the latter effect gives rise to a condition that is usually very beneficial for the separation of colloidal or colloidogenic substances. For example, when a suspensoid of tricalcium phosphate is passed through the centrifuge at too fast a rate to secure complete separation of the colloid, the discharged solution will in a few minutes contain only tricalcium phosphate in a completely flocculated state, and a second passage through the bowl, observing certain precautions, will easily remove the rest. This phenomenon has been found to apply to quite a number of things, among which may be mentioned fruit juices and suspensoids of alumina and ferric hydroxide. . . .

A little work was recently done on the centrifugal separation of suspended hydroxides of iron and aluminium from a saturated solution of a sodium electrolyte. The

concentration of the electrolyte was too great to get a maximum precipitating effect, but after about twelve hours the impurities had become flocculent. When the suspension in this state was passed through the centrifuge where it was subjected to a force quite competent to quickly remove the suspended particles, the latter were so broken up by the initial impact of the revolving bowl as to require a long-continued application of force to separate them. It was found that a trace of aluminium sulphate dissolved in the solution made the centrifugal clarification commercially successful. A peculiar fact is that when these same precipitates are in a much more dilute solution of sodium electrolyte, centrifugal separation is very rapid and complete without the addition of aluminium sulphate.

A certain pyroxylic lacquer contained a fine cloud of cellulose impurities. A suspension of this type can never be clarified by filtration, but will usually respond to centrifugal force. In this case, however, no reasonable amount of force would effect clarification, and yet on long standing the impurity flocculated and settled by gravity. The flocks were so unstable that the slight motion of a stirring rod was sufficient to destroy them. Very little is known of suspensions in organic media, and no expedient we have tried was effective in precipitating the impurity. The problem was finally solved, however, by adding a fractional percentage of tricalcium phosphate precipitated in alcohol. The filter press in this way produces an absolutely clear lacquer, whereas other filtering agents, such as kieselguhr, fullers' earth, bone black, barium sulphate, etc., were entirely without effect.

EMULSIFYING AGENTS

We come now to a discussion of emulsifying agents, a subject more important than all the rest to practical chemists.

Emulsoids may be enormously stabilized by the presence of certain substances. We would roughly divide the emulsifying agents into three classes: *First*, those whose presence in the minutest proportion will lead to a stable emulsion. Characteristic members of this class are the salts of the sulphuric acids of the naphthenic group, and certain complex ethereal esters. One drop of an oil containing the merest trace of these substances will cause a large volume of pure oil to become highly emulsifiable. We have mentioned these particular groups because they are at the heart of a big problem before the refiners of petroleum oil, but there are many others fully as interesting and troublesome, though of more theoretical value. It is characteristic of these compounds that their emulsifying properties depend upon their presence in the aqueous phase.

We do not make a distinction here between the disperse phase and the dispersion medium, for it is believed that emulsoids may have no phase that is not continuous. The condition has been described as an intricate network of one liquid within another. If the emulsifying agent is thrown out of solution in the water to the oil-slag phase, the emulsion is no longer stable, but can be separated by a very moderate application of force. For naphthenic agents, this interchange may be brought about either by salting out or by any reaction that will substitute a sulphonic salt more soluble in oil and less soluble in water. The emulsion can easily be broken also by a decomposition of the salt with strong sulphuric acid. The resultant separated oil will, of course, be highly emulsifiable because of the presence of the transposed agents.

Emulsions caused by the presence of ethereal esters can always be broken by distilling over caustic soda—sometimes in no other way.

A very high centrifugal force can cope successfully with this first class of emulsifying agents. The so-called "milk water," a weak emulsion thrown away by some of our oil refineries, can be completely freed from its oil without the addition of chemical reagents, but this procedure can hardly yet be called commercial. A certain lubricating oil contained a trace of an ammonium sulphonate. When emulsified with water the very highest centrifugal force generated was unable to separate it at commercial capacities. A slight dilution with a light oil, however, reduced its viscosity to such a point as to make centrifugal separation easy. The oil thus obtained was, of course, free from the emulsifying impurity and was not emulsifiable.

The second class of emulsifying agents must always be present in "excess" of the aqueous phase. The commonest examples of this group are the soaps of the ordinary fatty acids. Nearly all of the cutting oils of trade are made of oil, alcohol, water, and soap, and the stability of such emulsions is well illustrated by an analysis made of a standard product that was found to contain 82 per cent water. The principle underlying the action of soap in stabilizing the emulsoid appears to be its property of colloidogenesis, espe-

cially when in dilute aqueous solution. If an aqueous soap solution is agitated with a pure oil, the oil will extract the soap nearly completely, and the emulsion will be quite unstable. But the function of the alcohol is to increase the relative solubility of the soap in the aqueous phase, and it is clear that the reason for the excess of this emulsifying agent lies in the fact that the relative solubility in the oil is high, and that accordingly, even when the concentration of alcohol is great, much of the emulsifying efficiency of the soap is lost. Also, one may easily see that the soaps of calcium, aluminium or magnesium, prove much less efficient than those of sodium or ammonium. This class of emulsifying agents can be neutralized by liming, by salting, or by acid treatment, but rarely by caustic alkalis. In fact alkalis will usually act as a stabilizer.

We have in no instance found an emulsion of this type that cannot be easily separated by centrifugal force alone, and this is perhaps the most general field for centrifugal machinery.

Occasionally what appears to be a pure soap emulsion proves to be in reality an emulsion of the first class. For instance, a number of attempts have been made to purify the crude degrass recovered from wool by saponifying the fatty acids with soda ash, and separating the neutral wool fat by centrifugal force. The separation has been found difficult to accomplish in this way. The explanation is not soap. As any emulsion of purified neutral wool fat with aqueous soap can be readily separated, the real emulsifying agent in the case of degrass must be an unidentified ester present as an impurity. Proceeding on this assumption, we find that the difficult centrifugal separation of the degrass emulsion can be safely aided by such a reaction that will precipitate some of the soap without throwing the ester into solution in the fat. A little salt will answer the purpose. Lime will of course produce a poor fat because of the solubility of calcium soaps.

We hope it is unnecessary to point out the obvious fact that centrifugal separation of such emulsions is invariably made easier by dilution with water, not so much because of a reduction of viscosity, for this is not always the case, but because of the colloidal properties of soap solutions of high dispersity.

The third class of emulsifying agents appears to have a more or less mechanical function. A good example is finely divided or colloidal carbon. Each particle of carbon retains a film of water, exceedingly difficult to remove. Our experiments have shown also that the film of water is enveloped by a tenacious film of oil. No chemical treatment, except, of course, the use of some hygroscopic agent such as anhydrous calcium chloride, will break up such a condition.

The effect of centrifugal force on carbon emulsions is very interesting. If the liquid is passed through the centrifuge at a low rate, the carbon is thrown completely to the periphery of the bowl and the oil and water separately discharged. If on the other hand the rate is increased, so that the separating influence is exerted for a shorter interval of time, some of the carbon will be deposited in the bowl, while some will form a layer between the oil and the water and can be discharged with either. The ratio of "floating carbon" to that deposited in the bowl has been found to be as high as 50 per cent in some cases.

The Present Status of the American By-Product Coke Oven Industry

Mr. T. C. Clarke, consulting engineer of New York City, in a very interesting paper on the above subject, pointed out that now for the first time the American by-product coke-oven industry clearly sees daylight ahead in its struggle for recognition. In 1840 the first American bee-hive ovens were built; in 1894 the first by-product coke ovens were built in the United States. In 1894 the production of bee-hive coke in the United States was 9,187,000 tons, and the by-product coke production was 16,500 tons. In 1905 these figures had increased to 23,768,000 tons and 2,608,000 tons respectively; in 1910 bee-hive coke was 34,570,000 tons and by-product coke 7,138,000 tons. By the end of 1917, if all the ovens now built and building are in operation, the total by-product coke produced will be 24,000,000 tons, or within ten million tons of the record year's production of bee-hive coke (that of 1910).

The number of bee-hive ovens in operative condition in

1894, are given as about 30,000, as against by-product ovens of about 40; 1910 was the high water mark in bee-hive ovens, the total number being given as a little over 100,000. To-day the number of bee-hive ovens is reduced to about 95,000, whereas the by-product ovens now total 8677, with over 1000 of that number under construction.

Advance in pig-iron production during this period shows equally remarkable increases.

The average price at Connellsville for coke during this period was 1894, \$1; 1900, \$2.70; in 1905, \$2.26; in 1910, \$2.10; in 1913, \$2.95, and the market as quoted to-day is about \$3 at the ovens. An average of the past ten years shows the price to have been \$2.23 at the ovens with freight added to destination. With such a remarkable growth as shown by these figures before us, we can readily understand why the steel trade was called the barometer of the country's prosperity, but why the by-product coke oven was so slow in the beginning of its growth in this country, with its economic advantages so apparent, can only be understood by those who followed its early history.

Ovens as built here originally were from German plans and specifications and no consideration was given to the difference in the coking quality and analysis of the coals. In fact, beyond sending a few samples of coal to be coked in Germany, no attention was paid to the existing conditions, and the attempt was made to make coals adapt themselves to the ovens, rather than the ovens to the coals. In order to be fair it must also be taken into consideration that the first cost of the by-product coke ovens was very high as compared to the bee-hive; secondly, violent fluctuations in the coke market seemed to promise periodical shut downs of indefinite duration when earnings from the investment would cease, and lastly the blast furnace superintendents feeling they had in the Connellsville coke an ideal fuel, threw the weight of their influence against this innovation.

Those, like myself, who were fortunate enough to be in charge of by-product coke ovens at that time were impressed by the usual economic differences between foreign and American practice. Cheap labor permitted the German practice of from 28 to 36 hr. coking time with a four to five ton capacity oven, but American conditions all pointed to greater economy, if the coking time could be reduced, and the capacity increased. But to do that obviously required the entire redesigning of the ovens.

In the period from 1900 to 1906, tentative experiments were made but nothing was accomplished, although well defined theories that have since helped during the reconstruction period, were evolved.

I shudder to think of some of the costly repairs that became necessary due to our misguided zeal in trying to improve the coking time. We melted regenerators and walls in pursuit of scientific data. With the assistance of stack drafts and exhausters, we tried experiments with flues and gas burners, designed for 24-hr. operation, and managed to cut the time down, but our by-product yields were unrecognizable. The owners of the ovens suffered, but I think the results attained show that their suffering was not in vain.

Mr. Clarke then gave a brief description of the operation of an oven of the vertical-flue type with individual regenerators, and pointed out progress made in the course of years in details of operation. He emphasized that regularity in operation is of the greatest importance.

The by-product recovery method up to a short time ago was to cool the gas in condensers and pass it through a tar extractor. The ammonia was scrubbed out of the gas by passing in an opposite direction from the water through water towers, filled with wooden slats, and the resultant weak ammonia liquor was passed through a still with steam and milk of lime and the freed ammonia carried in the gases to lead lined saturators filled with sulphuric acid, where the salt was precipitated and dipped out by hand with copper ladles, centrifugally dried, bagged and shipped.

The gas then passed through the benzol scrubbers and the surplus gas, amounting to 50 per cent or more was available for power and lighting and the remaining gas was returned to heat the ovens. At the present time the so-called direct ammonia recovery process is almost universally employed. In the Koppers process, the gas leaving the ovens is first cooled to about 53 deg. C., this eliminating most of the tar. The ammonia liquor and the tar are separated by gravity, the liquor being treated as in the old process. The gas after passing through the tar extractors is returned to a heater, to be heated to about 70 deg. C. and is then passed through the sulphuric acid saturators as before.

In the Otto process, the gas is cooled down to about the dew point of steam by a 75 deg. C. tar spray. By not going to

a lower temperature the ammonia remains as vapor in the gas. While, of course a little of the ammonia liquor does appear, it is said to be much less than in the other processes. In the Otto process, on account of the gas being saturated with water vapor, the saturators are equipped with steam coils or the gas is superheated. In the German practice, and it is being adopted in our practice, naphthalene extractor follows.

To recover the benzol, the gas as it comes from the saturators is cooled to about 24 deg. C. and is then washed with what is known as straw oil, which is a petroleum oil with a specific gravity at 18 deg. C., of not over 0.875. Viscosity of not over 92 sec. at 21 deg. C. using a Saybolt viscosimeter; must yield no distillates below 285 deg. C. and must not thicken on cooling to 4 deg. C. After washing, the benzolized oil, containing about 2½ per cent of benzol and its homologues, is run to a light oil still, entering it at about 135 deg. C., where the steam drives off the light oil vapors which pass over to a condenser and the wash oil is returned to be used over again. From the condenser the light oils pass over to a fractionating boiler still where the 90 per cent benzol, toluol, etc., are secured. For the C. P. benzol and toluol a further operation of a washing with acid and caustic soda is performed and that product again distilled.

To increase the size of the oven charge required a larger oven, which in turn required more heat, and more heat required increased flue and gas area. The ramifications of this change are not only the larger ovens and methods of heating them, but increased size of off-take mains, cooling and recovery apparatus, pushers, quenching cars, coal and coke handling plants, mixing bins, etc.

These are the problems that confronted the engineers in the coke oven business. To their credit be it said, they overcame the difficulties arising from such a complete change. They did it with very few mistakes, and what they did, they did well.

About the time that this was being done a new factor which was a tremendous influence for good, appeared in the entrance of the United States Steel Corporation into the by-product coke industry.

The Steel Corporation's work in the industry has been of the very greatest advantage to all, as they have continuously experimented along lines which have benefited every one connected with coke ovens. The remarkable fuel economies in the blast furnace practice of to-day, can I believe, be attributed to the innovations they made.

There is one other feature that delayed the general adoption of the by-product oven in this country, and for that we must blame our bankers. In Europe we know that the chemical and its allied industries are looked upon as very attractive investments, while here our bankers are, or perhaps since the war began, I should say were, very slow to take up this kind of investment, but I think we may safely say that to-day a different feeling exists among them.

Were we not accustomed to having the mineral wealth of this country at our disposal, conservation would have demanded the installation of by-product ovens, for not only is there the direct loss of the nitrogen to the farmer and the valuable creosote oils for wood preservation, but even the coal itself is wasted to a startling extent in the old bee-hive oven. The yield of coke from a bee-hive oven is about 65 per cent, and from a by-product oven, with the same coal, about 75 per cent.

The metallurgical aspect of the situation brings conservation to our attention again. It was the habit of the coke producers of this country to put ovens as near the mines as possible, and the coal which was used was unmixed, and while during bad times it might have been a very good coke, during good times almost anything was shipped and accepted.

A by-product coke oven, located usually near the blast furnaces, solved a great problem for the steel makers. Coals were brought to the ovens and mixed. At first it was thought a fairly high volatile coal would not make metallurgical coke, and various mixtures of high and low volatile were made, depending on the individual's experience and convictions. To-day, however, a volatile of 30 per cent and over is being made into excellent metallurgical coke in a number of places.

The mixing of the coals developed the fact that even an inferior coke, if it was absolutely uniform, would show a fuel saving in the blast furnace. It was common practice to put in coke from perhaps two or three different operations. While the coke physically looked about the same, it could not, as a matter of fact, be counted on to be uniform, and in consequence the furnace was operating under varying conditions, a hard coke going in at one time and a soft coke at another. This obviously does not tend toward fuel economy. The charging of large and small pieces of bee-hive coke was usual, whereas to-day it is recognized that

crushing the coke to uniform size, while it increases the amount of breeze, thereby lowering the yield, works wonders in a blast furnace.

A second source of economy in furnace practice equally important is the ash. In a 400-ton-a-day furnace, 1 per cent of ash in the coke, using a fuel consumption of pound for pound would mean putting into the furnace 4 tons per day of a material costing \$4 a ton that not only is not valuable but that is positively detrimental. To flux this ash, stone must be added, and to melt the ash and the stone more coke must be added, then to flux and melt the ash in the added fuel the same cycle occurs, until the negligible point is reached. This gives an idea of what may be saved by the elimination of ash and the substitution of carbon in its place in the fuel. In this item alone selecting coal for its ash content justifies the added cost of better selection at the mines, cleaner mining, etc.

Uniformity enters prominently into the calculations, for with uniform by-product coke the furnace man burdens his furnace for a regular ash and sulphur content while with the fluctuations in the ash and sulphur of the bee-hive unmixed coke, he has to burden his furnace to take care of the worst possible condition, or else face furnace variations of operation. To put it another way he has to burn unnecessary fuel, put in unnecessary limestone, all taking the place of desirable oil to provide against the abnormal, or else have a furnace running hot one day and cold the next, with no certainty of product.

In the Chicago district the coke consumption per ton of pig iron has dropped from the old ratio of 2240 lb. of coke to 2240 lb. of pig iron to 1800 lb. per ton of pig, and I was informed two weeks ago when in Chicago, that some furnaces there were running under 1700 lb. Again referring to the statistics previously given on a production in the United States of 30,000,000 tons of pig per year, a saving of 400 to 500 lb. of fuel per ton of pig, with the fuel costing in the neighborhood of \$4.00 per ton, is conservation of coal and of money, and again shows what a great debt of gratitude we owe the pioneers in this industry.

As uniformity is the keynote to good practice in a blast furnace, so is regularity to the by-product coke oven. The practice to-day is to run everything on schedule and to make the heats conform to that schedule. Of course, this is only possible now that the regulation of nozzles, dampers, gas and air have been refined.

It was early seen that any coke oven that could be properly heated would make coke, so the competition lay in skill in design. Simplicity was the keynote and the design had to provide for easy access to all parts.

Mr. Clarke then gave interesting details in changes of design and costs, mention of which must be reserved for a future issue, and then took up the recovery of tar and ammonia, which is not as good in this country as in Germany and England. As the coking time was brought down, the yields of tar and ammonia went with it, and frankly as the coke ovens are principally being run to supply metallurgical coke this subject has not been given the attention that it deserves. The benzol industry is, with the exception of the Smet-Solvay Company, in its infancy. Plants are being built in practically every coke oven installation since the war began, and what the result will be after the war remains to be seen. Logically its first and greatest market will be as motor fuel.

The production of tar in gallons in 1905 was 36,370,000, in 1910 it was 69,780,000, and when the various plants now built and building are in operation these figures will advance to 237,947,000 gal. of tar. Sulphate of ammonia production in 1905 in the United States was 65,000 tons of 2000 lb., in 1910, 115,000 tons. When the present ovens now built and building are operating the production will be about 340,000 tons. The price of these commodities has been 2½ cents per gallon for the tar, and for the sulphate of ammonia around \$60.00 a ton for the past ten years.

When in Germany last summer, I became so thoroughly impressed with the necessity for preparation in this country, that I yield to no one in my desire to assist, in every way that lies in my power, toward that end. I fully appreciate the immediate necessity of being self contained in the matter of nitric acid, and not relying on Chilian nitrates.

I was told in Germany that they were securing the nitrogen necessary for munitions by the direct electric arc proc-

ess and by releasing the ammonia from the sulphate of ammonia and oxidizing it into nitric acid. This latter process, invented some years ago by a German chemist, was not commercially successful, on account of the cheapness of Chilian nitrate, but since the outbreak of the war it is one of the principal sources of supply. The abnormal conditions existing during a war justify the use of these more expensive methods of securing nitrogen, for the increased cost of these methods is negligible.

The Chamberlain bill, which I had supposed was for an increase in our army, seems to be broader in its scope, for I find it contains an amendment appropriating \$15,000,000 for a hydroelectric plant, for the production of nitrogen for the army during war times and for fertilizer in peace times. If this is a war measure, should not the government establish a number of plants around the country for converting sulphate of ammonia into nitric acid and should it not arrange with the many hydroelectric companies to take power from them during the duration of the war and secure direct nitrogen from the air? Should not the plants be broken up into small units, the geographical location of these plants being made with due regard to freight rates and the accessibility of material? I cannot seriously contemplate the government putting its entire reliance in one dam, which treachery or a bomb from an aeroplane could annihilate, thereby destroying the source of supply. We may well then question why the government contemplates this investment, and the answer seems to be that it wants to go into the fertilizer business, in competition with private capital that has invested millions of dollars in the same industry, or else why spend \$15,000,000 building dams to sell power to produce nitrogen for fertilizer purposes 99 per cent of the time during peace in order to have nitrogen 1 per cent of the time during war, when during that period they can get all the nitrogen they want from sources at present established. If private capital has never been able to make the direct recovery of nitrogen from the air by the electric arc process commercially profitable, why assume the government can?

It is then natural to assume that the only process that has found a foothold on this continent will be adopted, which is the cyanamid process; a process for the recovery of nitrogen from the air in the form of calcium cyanamid at a cost for power much less than the electric arc process. From this calcium cyanamid, the ammonia can be produced by further operations, and like the ammonia released from sulphate, oxidized into nitric acid. But why do this when sufficient nitrogen is already being recovered from coal?

I believe that the government has entered into this enterprise, believing that there is a nitrogen shortage, predicating this belief on the importations in the past of sulphate of ammonia. In 1914, the consumption of sulphate of ammonia or its equivalent, in the United States was 272,000 tons, of which the United States imported 83,000 tons, but as previously stated in 1907, the production will be 340,000 tons. The increase in consumption in the United States in the last three years, from figures available, is as follows:

	Consumption	Increase
1911.....	230,000 tons	16,000 tons
1912.....	246,000 tons	16,000 tons
1913.....	262,000 tons	10,000 tons
1914.....	272,000 tons	

This shows that the production is increasing in a greater ratio than is the consumption. Would it not seem reasonable then to suppose that the government would foster the sulphate of ammonia industry, and encourage the building of by-product coke ovens and arrange for securing in case of war the sulphate of ammonia, benzol and toluol necessary for the making of adequate munitions for such a war, and encourage further building of by-product coke ovens if the prospective amount of these materials was inadequate, rather than to build a hydroelectric plant? Private capital will in the future be just as ready to build ovens as it has been in the past, then why must the government spend \$15,000,000 to secure something private capital is producing now? If it feels it has to spend money, why not spend it on the sulphate of ammonia industry, where it will not only secure benzol and toluol for itself, but where, during the 99½ per cent of the time we are at peace, not only the farmer, the dye maker, the coal miner, the wood preserver, the tar paper manufacturer, the good road builder, the medicine compounder, but all those working directly and indirectly in the many ramifications of the coal tar derivatives will also be benefited?

The last paper of the evening was presented by Dr. R. L. Hallett on the volumetric determination of tin.

The Iron and Steel Market

The character of the steel market for some time to come, perhaps for the remainder of the year, has now become fairly well established. Buying for the distant deliveries has dropped to very small proportions, and in the circumstances heavy buying is not likely to be resumed in the near future. On the other hand, the mills are so well filled with orders, for both early and late delivery, that there is little if any opportunity for weakness to develop in the market. All steel requirements that could be foreseen and covered have been covered, and the current buying is chiefly to fill such requirements as cannot be foreseen, this involving a relatively small tonnage.

Thus, there is likely to be a relatively quiet market for several months, possibly to the end of the year, while the mills are operated at a feverish rate to fill the business now on books. This analysis of the situation does not suggest that the market will be dull or uneventful. The quietness indicated is merely relative, as compared with the intense activity and great excitement that have characterized the market in recent months.

The course of prices will probably be upward, though less sharply so than in the earlier months of the year, when stiff advances were the rule in substantially all products. As active buying for far forward delivery has already ceased the mills have nothing to conserve in that direction, and will feel free to make further advances from time to time on such deliveries as can be made, in case circumstances should support such a course.

It is commonly said that the current high prices for steel will operate to curtail consumption very materially. In the abstract the statement is undoubtedly true, but in the concrete it does not apply to a period as far ahead as steel market vision usually attempts to penetrate, for with the volume of business now on mill books, with such additional business as would be placed from month to month even in a very quiet market, the steel mills are sold for nearly a year ahead.

The bearing of some of the prospective decreases in consumption, due to high prices, may be analyzed. It is commonly assumed that new construction involving fabricated steel will be light, but in this connection it is to be noted that the Bridge Builders' and Structural Association reported that its bookings of fabricated steel work in March represented 102 per cent of the fabricating capacity for a month, while the average of the bookings in the five months ended with March was 94 per cent of capacity. No single month preceding for two years has shown bookings at 94 per cent, and the business now under contract will involve deliveries of plain material for months to come. Some of the structural shops no doubt have steel under contract at relatively low prices, whereby they can book some additional structural business, and the structural mills have an unusually large tonnage of shapes for ship building on their books, so that they are fairly well taken care of for many months.

Again, it may be observed that while freight-car buying is now light, there have been orders for at least 6000 freight cars placed in April, while the orders since Jan. 1 total more than 50,000 cars, with an equal number placed in the last quarter of last year, and a large portion of these cars are still to be delivered.

Notice has been given that standard steel rails, which have been substantially unchanged in price

since February, 1901, will advance May 1 by \$5 a gross ton, from 1.25c. to 1.47½c. in the case of Bessemer, and from 1.34c. to 1.56½c. in the case of open-hearth.

General advances have been made in welded steel tubular goods. New lists dated April 15 advanced boiler tubes four points, or about \$8 a ton, to a basing discount of 56 per cent, and oil country goods by an average of about \$2 a ton. Lists dated April 21 advanced standard steel pipe and line pipe from two to five points, according to size, and galvanized steel pipe an extra point.

February exports of such steel products as are reported by weight amounted to 369,000 gross tons, showing a slight gain over any of the four preceding months, but a loss as compared with July, August and September. There appear to have been increases in the exports of the various manufactures not returned by weight but involving steel in their manufacture, so that the volume of steel involved in exports, direct and indirect, may be regarded as substantially constant, at about 25 per cent of the total output.

The statement of Mr. E. R. Stettinius, of the Morgan firm, that there would be few "war orders" in future, has not aroused much interest in the steel trade. The orders now on books, for war and other steel, will carry the mills for many months. For months the backbone of the steel market structure has been the domestic demand.

After all, the steel trade is much more concerned with operating and transportation problems than with market problems. The market will take care of itself for many months, while operating and transportation present their difficulties. The general wage advance in the iron and steel industry on February 1, and averaging more than 10 per cent, proves not to have settled the wage matter indefinitely, for in the second half of April another wage advance was precipitated by circumstances. This second advance amounts to fully 10 per cent and becomes effective May 1. As to transportation, a general blockade developed on the eastern roads early in December and the situation has improved but slightly in recent weeks. Fears are entertained of fresh difficulties in the Central West when the vessel movement on the Great Lakes gets under full swing. The first Lake Superior ore was loaded on vessel April 18, at Escanaba, Duluth following a few days later.

Pig Iron

The possibilities of the pig iron market become more interesting as time passes. April has been a dull month in actual turnover, as compared with the activity of March, but the possibilities of a shortage in steel making pig iron in the Central West have been accentuated, chiefly through the prospect that the large steel producers, normally self contained, will be forced to enter the market to supplement their own production. About the middle of April the Youngstown Sheet & Tube Company bought the Andrews & Hitchcock Iron Company, operating two merchant furnaces at Hubbard, Ohio, and yet a few days later it bought 60,000 tons of Bessemer iron in the open market. The Republic Iron & Steel Company has bought at least 15,000 tons of basic iron. In the past few months stocks of merchant iron have been decreased, while the full merchant output is being realized and the steel works are to bring in much new steel making capacity in the next few months. We quote No. 2 foundry iron, delivered Philadelphia, \$20.25 to \$20.75; f.o.b. furnace, Buffalo, \$18 to \$18.50; delivered Cleveland, \$19; f.o.b. furnace, Chicago, \$18.50; f.o.b. Birmingham, \$15 to \$15.50; f.o.b. valley furnaces, 95 cents higher delivered Pittsburgh; Bessemer, \$21 to \$21.50;

basic, malleable and foundry, \$18.50 to \$19; forge, \$18 to \$18.50.

Steel

There is no regular market for ordinary soft steel billets and sheet bars. Nominally the market may be quoted at about \$45 for Bessemer and \$45 to \$50 for open-hearth, either billets or sheet bars, with ordinary rods at \$60 and high carbon rods at \$75 and upward. There is considerable activity in billet discards arising in the production of war steel. These discards are directly suited to few operations but in the circumstances find a fairly ready sale at various prices, generally at \$40 or higher.

Iron and Steel Institute

The annual meeting of the Iron and Steel Institute is scheduled for May 4 and 5, 1916, in the House of the Institution of Civil Engineers, London. General business will be transacted and the president-elect, Sir William Beardmore, will be inducted into office. The Bessemer gold medal for 1916 will be presented to Mr. F. W. Harbord, and the award of grants from the Andrew Carnegie Research Fund will be announced. The following list of papers will be submitted for discussion:

L. AITCHISON: "Notes on the Theory of the Corrosion of Steel."

J. O. ARNOLD: "Notes on the Relations Between the Cutting Efficiencies of Tool Steels and Their Brinell or Scleroscope Hardnesses."

C. BENEDICKS: "A New Thermo-Electric Method of Studying Allotropic Changes in Iron or Other Metals."

C. A. EDWARDS: "Initial Temperature and Critical Cooling Velocities of a Chromium Steel."

SIR ROBERT HADFIELD and J. N. FRIEND: "The Influence of Carbon and Manganese Upon the Corrosion of Iron and Steel."

A. MALLOCK: "Early Experiments on the Recalescence of Iron and Steel."

W. N. THOMAS: "A Few Experiments on the Hardness Testing of Mild Steel."

F. C. THOMPSON: "Surface Tension Effects in the Inter-crystalline Cement in Metals and the Elastic Limit."

Non-Ferrous Metal Market

Tuesday, April 25.—Copper and silver have made notable advances during the last two weeks, while the other metals have remained steady or have declined slightly. There have been no new startling developments.

Copper.—The price of spot copper has risen about 2 cents during the last two weeks, and electrolytic is now quoted at 30 to 31 cents, with prime lake at 29.50 to 30 cents. Prices have been irregular for nearby deliveries, but the above quotations are fairly representative of the market. There has been considerable buying by home consumers. May and June electrolytic is quoted at 29.00 to 30.00, with prime lake at 29.00 to 29.50. July and August quotations are 28.50 to 29.00 for electrolytic and 28.00 to 29.00 for lake.

Tin.—The tin market has been uncertain and much influenced by the difficulty in getting supplies. The demand has not been especially good and prices have reacted. Spot tin is now quoted at 50 cents.

Lead.—The lead market for the most part has been dull, with no further advances made by the Trust during the last two weeks. Prices in the outside market are slightly higher, but the demand for premium metal

has fallen off considerably. Lead is quoted as follows: Trust price 7.50, outside 7.50 to 7.62½.

Spelter.—Considerable activity was displayed in the spelter market during the second week in April, but since then the market has been dull, with a slight reaction in prices. Spelter is now quoted at 18.80 cents.

Other Metals.—Antimony has declined slightly, due to a quiet market, and is now quoted at 40 cents. Aluminium remains practically unchanged at 60 cents, platinum is still quoted nominally at \$88 per oz., while silver continues to rise and is now quoted at 65½%. Mercury has declined about \$15 per flask, and is now quoted at \$125.

Metallurgy of Tin Ores in Bolivia

At the recent Pan-American Scientific Congress Mr. S. E. HOLLISTER presented a paper on this subject, of which the following is an abstract:

Present tin-milling methods, except in the case of a very few companies, are little different from those practiced years ago. This condition is gradually changing and the tendency is toward better methods and greater savings. The principal ore is the oxide, cassiterite. Mining is yet in the high-grade stage, the mills in most cases treating 10 per cent ore. In the past a large part of the production has been from very high-grade shipping ore. This has been the salvation of some of the present large companies, counterbalancing the wasteful operations in their other departments. With the exhaustion of the present high-grade deposits, plants must be equipped to treat low-grade ore, of which there are large reserves.

The plants are nearly all equipped to treat oxidized ores, those found first in mining operations in this country. With the pyritic ores, encountered at depth, the milling becomes more complicated and requires different machinery. Several companies are now using automatic-roaster, magnetic-separator plants for the separation of the cassiterite and pyrite. This is proving satisfactory.

Arsenopyrite causes trouble because of penalties imposed by the smelters for arsenic, but this is kept within the contract limits by mixing with clean concentrates or by roasting.

Except in the district of Potosi, no tin is smelted in Bolivia. There a little low-grade concentrate is treated, a tin of about 95 per cent purity resulting.

Placer mining, except in small operations, is not practiced. The various districts have been prospected and several reported upon favorably, but no further action has as yet been taken.

Labor is cheap but not efficient. Holidays are numerous. This, in combination with expensive supplies, materials, and transportation, makes mining and milling in Bolivia difficult. However, conditions are becoming better, and with the United States wanting tin to smelt, business relations between the two countries should improve.

Effect of Certain Pigments on Linseed Oil.—In a recent publication of the Bureau of Standards (Technologic Paper No. 71) the results of investigations on this subject are given. No marked chemical changes were found to occur in white-lead linseed-oil paste during storage. Preliminary data were obtained on the composition of drying films from white lead and white zinc paints.

The Aluminum Company of America, Pittsburgh, is contemplating the erection of a clubhouse 75 by 200 ft. at New Kensington, Pa. The building will be used by the officials and skilled employees of the company.

Niagara Falls Power and American Industries

A Symposium of Papers Presented at the Washington Meeting of the American Electrochemical Society on April 27, 1916

I. The Power Development

BY I. R. EDMANDS.

There are a great many people in the United States who believe that the scenic grandeur of Niagara Falls has been seriously impaired or entirely ruined by the diversion of water for power developments adjacent to the Falls, and many of these people have loudly denounced the power companies, the users of power and even the government, without taking the trouble to investigate the truth of their statements.

We wish to present some of the facts pertaining to the use of water for the development of power at Niagara, so that the situation may be better understood.

There is a treaty between the United States and Great Britain in regard to the use of boundary waters between the United States and Canada, and it definitely agrees on the amounts of water that may be used on each side of the river at Niagara Falls. This treaty went into effect in May, 1910, and following is a paragraph relating to the diversion of water for power purposes:

"The United States may authorize and permit the diversion within the State of New York of the waters of the river above the Falls of Niagara for power purposes not exceeding in the aggregate a daily diversion at the rate of 20,000 cubic feet of water per second,"

and it permits

"the diversion within the Province of Ontario of the water of said river above the Falls of Niagara for power purposes not exceeding in the aggregate a daily diversion at the rate of 36,000 cubic feet of water per second."

"This shall not apply to the diversion of water for sanitary or domestic purposes or for the service of canals for the purpose of navigation."

This permits a total diversion from Niagara Falls of 56,000 cu. ft. of water per second from an average flow of the Niagara River of 212,000 cu. ft. per second, or a diversion of 26 per cent of the average flow.

The quantities permitted in the treaty were not determined until a thorough investigation of the diversion of water had been made by government engineers as to what effect, if any, this diversion would have on the scenic grandeur of Niagara Falls and the effect on navigation in Lake Erie and the Niagara River.

Previous to the 1910 treaty the use of 15,600 cu. ft. per second had been allowed by the Burton bill for power purposes in New York, with the possibility of having this increased if for a period of six months it had all been used.

The treaty has now been in effect for six years. The power companies on the United States side of the river have for years used all the water which the government will allow, which is 4400 cu. ft. per second less than the treaty provides. Notwithstanding the great demand for more power in the United States, this 4400 cu. ft. of water per second is going to waste over the Falls.

The power companies have asked the government for permits to use it and are ready and desirous to convert it into electrical energy, but the United States Government withholds the necessary permits. This 4400 cu. ft. per second is capable of developing about 80,000 hp. If this amount of electrical power were developed by steam power, it would require a ton of coal every min-

ute, or 525,600 tons per year. Is this worth saving? It certainly is and should be, if it can be saved without destroying the scenic grandeur of Niagara or without adversely affecting navigation.

The United States Government Engineers' investigation was under way for four years previous to the signing of the treaty and was very carefully and scientifically made and covered in a report to the Sixty-second Congress, Senate Document 105 and H. R. Document 246. The conclusions from the Government Engineers' reports regarding the American Fall were that about 5 per cent of the flow of the Niagara River goes over it and that there is no lessening of scenic grandeur due either to water diversion for power purposes or from natural causes. The conclusions reached regarding the Horseshoe Fall were that the scenic grandeur had been impaired by depletion of water at the extreme ends of the horseshoe, but that this is principally due to natural causes.

The impairment to the Horseshoe Fall is principally due to the recession of the rock at the apex of this fall, which diverts the water from the sides of the horseshoe. Any diversion of water for power purposes tends to still further reduce the flow over the sides of the horseshoe, but the report states that the lessening of the flow over the sides "and that which may be anticipated from further diversions and from lower stages in Lake Erie may be largely, if not entirely, remedied by a submerged dam placed in the bed of the river immediately above the Horseshoe Fall, with the object of diverting a portion of the great volume passing over the center or apex of the Horseshoe so as to increase the depleted ends of that fall, and, incidentally, diminishing the rate of recession of the apex."

Although the remedy for the thinning of the flow of water over the ends was shown to be practical about eight years ago, there has been no attempt to apply it by either of the governments interested or by anyone else.

If the scenic grandeur of the Horseshoe Fall has been lessened by either water diversion for power purposes or from natural causes, then the governments interested should without delay follow the advice of their engineers and put in the submerged dams. The question of expense would not hinder this project, as it is small in comparison to the enormous value of water for power purposes and the great value to the public as one of the greatest scenic wonders of the world. Doubtless the power companies would stand their respective shares of the expense without objection. Why, then, has not this remedy been applied? The only logical reason to those familiar with the visible features of the Falls is that the impairment of scenic grandeur has been so slight that it is not considered worth while to take any trouble or expend any money for the possible improvement. The same conclusion is reached in the same way in regard to navigation. The same Government Engineers' report previously referred to states "that the investigations have established a real, though relatively small reduction in the depth of Lake Erie, amounting to 0.07 ft. (2.1 cm.) for the present authorized diversion." This can also be compensated for by remedial dams or weirs in the Niagara River.

Maintaining the elevation of Lake Erie water level is

of tremendous commercial importance to the shipping interests, and the cost of building remedial works is insignificant compared to the interests involved; but, notwithstanding this, no attempt has been made to build remedial works up to the present time.

Why should remedial works be built to compensate for the variation of the level of Lake Erie of about 1 in., due to water diversion for power purposes at Niagara Falls, when the variation of the Lake Erie level by natural causes, rainfall and varying winds is about 14 ft.?

Another artificial diversion of water from Niagara Falls is made by allowing the water from Lake Michigan to flow through the Chicago Drainage Canal into the Illinois River and thence through the Mississippi River to the Gulf of Mexico.

At the time of making the treaty regarding the division of water for power purposes at Niagara Falls between the United States and Canada, it was assumed that the Chicago Drainage Canal would take 10,000 cu. ft. per second, and this accounts for part of the difference of the unequal division of water there by the treaty.

The principal importance of the diversion of water through the Drainage Canal is for the carrying away of Chicago's sewage and, incidentally, some power is developed at Lockport, Ill., at approximately 30 ft. head. The operation of the Drainage Canal with the full flow of 10,000 cu. ft. per second is not allowed by the United States Government, but it is operated at about 7000 cu. ft. per second. Therefore, there is about 3000 cu. ft. per second which was contemplated being diverted from Niagara Falls when the treaty was made, but is not now used. If this is properly used for power purposes at Niagara Falls it represents 60,000 hp., or the equivalent of 390,000 tons of coal per year if this amount of power should be developed by steam.

Considering the use of water for power purposes as between Niagara Falls and Lockport, Ill., the same quantity of water will develop about seven times as much at Niagara on account of the greater "head" there, so no more water should be diverted through the Chicago Drainage Canal than is absolutely needed for sewage purposes. Even using water for this purpose at this place is open to criticism. The emptying of large quantities of sewage into streams passing through many villages, towns and cities is ever a menace to the health and comfort of the members of the communities through which they pass and can be considered only as a relic of old and antiquated methods.

There are two large power companies on the United States side of Niagara Falls and three on the Canadian side. A small amount of water is allowed for power purposes from the Erie Canal in New York State and also some is allowed for power purposes from the Welland Canal in Canada. Both of these uses divert water from Niagara Falls.

The total amount of water now being used at Niagara and on the Erie Canal in the United States is 15,600 cu. ft. per second, from which about 215,000 hp. is developed, and this is all used in the United States. The total amount of water now being used at Niagara and on the Welland Canal in Canada is about 29,000 cu. ft. per second, from which about 360,000 hp. is developed, of which about 175,000 hp. is transmitted to the United States. The total amount of water diverted from Niagara for power purposes in both the United States and Canada, but not including the Chicago Drainage Canal, is 44,600 cu. ft. per second, which represents a total power development of 575,000 hp., 185,000 hp. being used in Canada, and 390,000 hp. in the United States.

The grants or permits under which the power companies on the Canadian side were built provided that

half of the output of the power houses on their side should be reserved for Canadian demand when wanted. Nearly one-half of the combined output from the various power houses on the Canadian side is now being transmitted to the United States and, therefore, there is little prospect of further relief for the demand for power on this side of the river from Canada. The development of additional power in Canada is needed there, and this will undoubtedly be completed up to the full amount of water limited by treaty as soon as the actual work can be done.

Aside from protecting Niagara Falls from the possibility of too much diversion of water for power purposes, something must be done and done soon to preserve the Horseshoe Fall from itself, for it is literally "eating itself up." The recession of rock at the apex, due to the action of the large quantity of water flowing at that place, is going faster and faster. Over the period from 1875 to 1906 the recession averaged 5 ft. (1.5 m.) per year, and since then about 8 ft. (2.4 m.) per year, and during one of the recent years a great piece of rock fell out, making a noticeable change in appearance of the apex. The more the rock recedes, the more the water is diverted from the sides of the Horseshoe and the larger the quantity of water going into the gap made by the recession. How long will it take before the scenic grandeur is destroyed? Nobody can say, but this is certain, that the Horseshoe Fall is changing and the changes in the future will be much more rapid than the changes in the past, and, if we do not wish to take a chance that the changed fall will soon be much less of a great world spectacle than now, the recommendation of the Government Engineers should be followed and submerged dams built to distribute the water to give the best scenic effect and to prevent further serious recession of the apex.

An eminent engineer, resident at Niagara Falls, who has made a careful study of the hydraulic and scenic conditions lasting over a period of many years, is of the opinion that by the placing of submerged weirs just above the apex of the horseshoe and at the upper end of the rapids above the Falls, double the amount of water allowed by the treaty, or about 50 per cent of the total average flow of the Niagara River, could be diverted from the Falls without serious detriment to their scenic grandeur.

If this opinion is correct, think of what economic importance it is to the people and industries within commercial transmission distance of Niagara and, more or less indirectly, for many industries scattered over the United States and Canada.

An additional 25 per cent of the average flow of the Niagara River, if properly converted into power, would equal about 1,000,000 hp., or the equivalent of 6,500,000 tons of coal each year if produced by steam power.

It is a crime to ourselves to waste such an opportunity for the development of industries, transportation and domestic conveniences, and a crime against future generations not to conserve our natural resources.

After carefully considering the interests of the public in the scenic grandeur of the Falls, the benefits to them of cheap and ample power, the interests of navigation in the upper Niagara River and Lake Erie, the interests of the industries whose existence depends on low-priced power in large quantities, and the interests of the power companies, it appears that the United States Government, through the Secretary of War, who now has the authority, should without delay grant to the United States power companies the right to use the 4400 cu. ft. of water per second still allowable under the treaty, and then the two governments should jointly proceed with the recommendations of the engineers by the building of the submerged dams and remedial works,

thus protecting the Horseshoe Fall from self-destruction, maintaining the scenic grandeur of both falls, improving navigation in the upper Niagara River and Lake Erie, and making it possible to still further divert water for power purposes, thereby conferring a great benefit on the population within electrical transmission distance and conserving our natural resources.

How will these questions of such great importance be decided?

There are many independent interests involved and these must be brought together and unite on the best course to pursue.

This Society might invite representatives of all the parties interested to form a commission, to investigate all features in connection with preserving the scenic grandeur of Niagara Falls, the diverting of additional water for power purposes and the improving of navigation.

It is suggested that representatives be invited, one each from the Dominion of Canada Engineers and the United States Government Engineers, one each from Canada and the United States representing the public interest in the scenic grandeur of the Falls, one representative for the Canadian power companies and one for the United States power companies, one each for the Canadian and United States industries using Niagara power and one each from Canada and the United States representing navigation interests. This commission should be empowered by the interests they represent to energetically spend as much time and money as is necessary to obtain the information and engineering data and, within reasonable time, formulate recommendations and submit them to the Secretary of State of the United States and the Governor General of the Dominion of Canada for action.

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II. Electric Furnace Products

BY F. J. TONE

The development of Niagara power in 1895, only twenty years ago, marks the beginning of the electric furnace art. It stands to-day as one of the big factors in our industrial life. Up to 1895, when Charles M. Hall came to Niagara, the aluminium industry depending on steam power had given little promise of commercial success. Its almost incredible development during twenty years has been due to the impetus of Niagara power, and its future magnitude no one dares to predict. Dr. E. G. Acheson with a 150-hp. furnace operated by electric power generated from steam had made a commercial failure of carborundum. Coming to Niagara in 1895 he was at once enabled to found the artificial abrasive industry. Willson, the inventor of calcium carbide, was working at Spray, N. C., with a 200-hp. furnace. To-day we have 12,000 to 15,000-hp. furnaces making almost as much carbide in one day as the former furnace produced in a year.

With the technology of these great industries, aluminium, calcium carbide, cyanamid, abrasives, ferro-alloys, silicon and graphite we are all familiar, but few realize their economic importance or to what an extent the industrial and metallurgical arts are indebted to Niagara power for their development. At this time, when we are taking stock of our industrial assets and determining how the nation can best make itself industrially self-contained, it is well to point out how the products of Niagara power are bound up with this whole broad question.

FERROSILICON

The manufacture of steel is the greatest of all American industries, and its dependence on Niagara power

is strikingly illustrated by a study of the ferro-alloy industry. In 1915 the estimated production of finished steel in the United States was 28,000,000 tons, and in a major portion of this there was employed as the chief deoxidizing agent high-grade electrically produced ferrosilicon. This alloy is used in practically all steel manufactured by the basic open-hearth process, which in recent years has so far supplanted the Bessemer process as to account for more than 70 per cent of the total production. To a lesser extent electrically produced ferrosilicon is used in almost all the other processes of steel manufacturing.

The steel-casting industry finds high-grade ferrosilicon practically indispensable for eliminating blowholes and producing sound castings. The extension in the use of cast steel as a material of engineering during the past twenty years is due primarily to an adequate supply of high-grade ferrosilicon, insuring complete deoxidation of the molten steel. The cast-iron foundry industry has in recent years realized the advantages of the use of high-grade ferrosilicon, and progressive establishments now depend on this alloy for a control of their castings.

Niagara Falls is the home of ferrosilicon in the United States, and up to the present time the total domestic production has been made from Niagara power. For a short time prior to the European War some ferrosilicon was imported, but a large portion of this was produced by Niagara Falls power in Canada. The Canadian producer has, since the war began, been compelled by government order to export ferrosilicon to countries other than the United States, thus increasing an existing unprecedented demand for the domestic product and causing a power famine on the American side of the Niagara River. This fact has a significant bearing, not only on the inadequacy of the total supply of Niagara Falls power, but on the regulations which govern the importation of electrical energy into the United States. A cessation of the supply of ferrosilicon would be nothing short of a calamity to the steel business, and when we further consider that specifications for shell steel for munition purposes call for 0.20 to 0.30 per cent silicon, we see the rôle ferrosilicon plays in munition manufacture and the realization of our own program of preparedness.

FERROCHROMIUM

The essential element in the manufacture of successful armorplate and armor-piercing projectiles is introduced into steel by the alloy ferrochromium. It is strictly an electric furnace product. Without this alloy not a battleship could be provided with protective armor nor a coast defense gun served with modern projectiles. More than one-half of that now consumed in the United States is produced at Niagara Falls. Ferrochromium likewise enters into the manufacture of automobile steels, steels for jaws, balls, linings of crushing machinery, dies and a variety of special steels.

Sir Robert Hadfield has compared the striking energy of an armor-piercing projectile with that of a modern express train. He states that a 14-in. (35 cm.) projectile weighing 0.62 ton and fired so as to pierce 12-in. (30 cm.) armor plate at a distance of eight miles (13 km.) must have a striking energy of 30,000 foot tons (9000 m. tons) and a striking velocity of 1700 ft. (510 m.) per second, or twice the energy of a modern express train running at forty miles (67 km.) per hour. The shell has 1/8000 the bulk of the train, and the metallurgist has been able to provide a shell having a steel point of such quality that it delivers this concentrated energy upon the hard-faced plate and passes through it without suffering deformation. This is a striking metal-

lurgical achievement, but it is the electric furnace and ferrochromium that have made it possible.

TUNGSTEN-VANADIUM-MOLYBDENUM

These alloys are made in part from Niagara power, and when made elsewhere there is largely used as a reducing agent metallic aluminium, also a Niagara product. They form the chief constituents of a relatively high-priced group of products representing an annual production of several millions of dollars, and which in conjunction with chromium are absolutely necessary in the manufacture of high-speed tool-steel, magnet-steel, certain gun-steels, and a variety of special steels. High-speed steel furnishes a most striking example of the dependence of the metal-cutting industries on products of Niagara power. To one familiar with machine-shop practice under the limitations of carbon steel, where it was necessary to maintain a cool cutting edge, it is amazing to see a 17-in. (43 cm.) forged shaft destined for some battleship revolving at a surface speed of 30 ft. (9 m.) per minute, the tool of high-speed steel working at red heat, and chips $1\frac{1}{2}$ in. (4 cm.) wide and $\frac{3}{8}$ in. (1.4 cm.) thick coming off, colored a deep blue. Ferrochrome and the other alloys of this group have made this possible. High-speed steel has tripled the capacity of every machine shop in the world and the efficiency of every workman. It has cut to one-third the capital invested in tools to accomplish a given volume of work.

Considering the metals or alloys of chromium, tungsten, vanadium and molybdenum as a group, it may be positively stated that in the absence of these products we should not be in a position to build modern battleships, guns, submarines and many other machines necessary for the nation's defense, to proceed with thousands of operations involving the cutting of metals at a rate comparable with the present or necessary to successfully meet foreign competition. A goodly proportion of our steel and metal working industries, mining operations and scores of other industries would find themselves in the condition of practically twenty years ago.

FERROTITANIUM

Titanium as a ferroc carbon-titanium alloy is employed in a large tonnage of steel made by the Bessemer and open-hearth processes, as well as in the production of steel and iron castings. The aluminium bronze and other non-ferrous alloy industries are being greatly benefited by the use of titanium alloys. It is worthy of note that the smelting of titanium alloys by other than an electric furnace process is not a commercially practicable undertaking.

SILICON METAL

A special steel of great importance to electrical industry is silicon steel, used in electrical transformer construction and all alternating-current apparatus. Silicon metal and 75 per cent ferrosilicon essential in its manufacture are produced only at Niagara Falls. The ageing of transformer steel has long been the cause of a serious falling off in efficiency. The loss often doubled after a few years' use. Silicon steel does not age. Moreover, its original hysteresis loss is 25 per cent less than that of the old type of steel. The saving in a large generating and distributing system from the generator through step-up and step-down transformers to the motor may be as high as 6 per cent. Thus silicon steel, a comparatively unknown product, is saving many millions of dollars annually wherever electric energy is transformed.

Silicon metal as a "preparedness" product is im-

portant in the generation of hydrogen for aeronautical purposes. In conjunction with caustic soda it forms the cheapest method of generating hydrogen in the field or on shipboard when portable outfits are required.

ALUMINIUM

The manufacture of aluminium is the largest of the electrochemical industries in point of power consumed and value of product. Commercial development was made possible by Niagara power, and Niagara Falls was for many years the only seat of the industry. The chief uses of aluminium are in automobile and aeroplane parts, electric transmission lines, cooking utensils, acid containers, the deoxidizing of steel and aluminothermic welding. Even with the prodigious increase in production the scarcity of aluminium is to-day very acute and is regarded by automobile engineers as little less than a calamity.

ABRASIVES

The electric furnace abrasives, carborundum and alundum, are fundamental elements in the metal-working industries. They have revolutionized the methods of finishing machine parts, just as high-speed steel has revolutionized the art of shaping metals by cutting. Artificial abrasives have been gradually displacing natural emery and corundum, until in 1914 they constituted 62 per cent of the total abrasives used in the United States. The natural abrasives have practically all been imported, and comprise Turkish and Grecian emery. With the beginning of the war, mining in Greece and Turkey ceased and artificial abrasives have been called on to supply the whole field. There are five plants making artificial abrasives from Niagara power, three of which are on the American and two on the Canadian side of the river.

The great metal-working industries making agricultural implements, locomotives, cash registers, electrical machinery, firearms, flour-milling machinery, paper machines, automobiles and all castings of steel, iron and brass are entirely dependent to-day for an adequate supply of grinding materials on Niagara power. As a simple example, take the automobile industry. The mechanical perfection of the modern automobile and the interchangeability of parts have been made possible only by the development of the grinding machine and the grinding wheel. Practically all parts of an automobile are finished with abrasives at some stage of their manufacture. Crankshafts are roughened and finished with grinding wheels, likewise camshafts, pistons, cylinders, and all forgings and castings. It is impossible to produce ball bearings and roller bearings without the use of grinding wheels. Cut off the artificial abrasives and force the automobile manufacturer to go back to the grindstone, at the same time eliminating the other products of Niagara power, aluminium, high-speed steel and special steels, and we would see a works which now produces 500 cars per day reduced to an output of considerably less than 100 cars, with the same force of workmen and the same plant equipment. This would mean such an increase in price that there would be no automobile industry on its present existing lines.

Manganese steel, one of the unique materials of engineering, was little known fifteen years ago. To-day the output in frogs and switches, burglar-proof safes, dredges, gears and rolls represents many millions of dollars. No steel tool will cut it. Without grinding wheels to shape and fashion manganese steel it would still be a metallurgical curiosity.

CALCIUM CARBIDE.

This electric furnace product is the only commercial source of acetylene. Its principal uses are in the light-

ing of small towns, isolated hotels, institutions and factories, in the lighting of railway trains and harbor buoys, in the form of portable lamps for miners and automobiles, and in a more recent and exceedingly important application of this gas to the oxy-acetylene cutting and welding of metals. A cessation in the domestic production of calcium carbide would entail enormous loss. Had we to do without acetylene lighting and the recent application of the oxy-acetylene flame in the welding of metals, in the building as well as the razing of large metal structures and as a means of effecting economies in a great variety of other ways, we should as a nation be compelled to work at a slower and less efficient rate than our competitors in many of the metal industries.

Calcium carbide is the material from which is produced calcium cyanamid, the most important compound today in the field of fixation of atmospheric nitrogen, and the source of supply which could be most promptly and positively relied upon to solve the problem of an adequate supply of nitric acid and nitrates employed in munitions of war in the event of a failure of the supply of Chilean nitrate. To manufacture these products to the extent required for self-preservation would necessitate a much larger diversion of water of the Niagara River than is at present permitted.

ARTIFICIAL GRAPHITE.

An electric furnace industry that owes its inception and entire development to Niagara power. The production, which totals several thousand tons annually, falls in two general classes, electrodes and powdered graphite.

Graphite electrodes are used exclusively as anodes in all electrolytic cells for the production of caustic and chlorine. They are a fundamental requisite of this vast industry. With the supply of platinum cut off they are now replacing this expensive metal as anodes in the electrolytic chlorate processes. Graphite electrodes are extensively used in electric smelting and refining furnaces, producing high-grade steel, alloy-steels, ferro-alloys, copper, zinc and nickel.

The chief uses of powdered graphite are in dry cells, paints and lubricants. Every one of the millions of flash-light batteries produced in this country contain artificial graphite.

All the manufactured graphite used in the world is produced at Niagara Falls. It occupies a field of its own, which cannot be filled by natural graphite, and it is another striking illustration of the electric furnace "going nature one better."

Thus we see that the electric furnace is not merely a new metallurgical tool but an important element in our economic life. Dr. E. F. Roerber, in a remarkable address before this Society, once pointed out that we need a revaluation of our aesthetic values. There is beauty in electrochemistry. There is beauty in ferro-chromium, when high-speed steel cuts human toil in half. There is beauty in fixed nitrogen, when it feeds a teeming population. When future generations begin to shiver for want of coal and to starve for want of nitrogen, the present generation will be remembered not as champions of the preservation of scenic beauty but as champions of the ugliness of wasted resources.

* * *

III. The Chemical Industries

BY A. H. HOOKER

It is interesting to note how a despised and perhaps, for the time, a harmful by-product, may develop into the chief product of an industry, and a shortage seriously affect the general comfort and economy of our lives.

Just now gasoline is an every-day example. In the time of the early coal-oil lamp, many dangers lurked in the poorly refined oil, and every effort was made to increase the yield of high-flash kerosene and remove for this reason gasoline from the oil. This gasoline was then little more than a waste product, to be disposed of when possible or thrown away and allowed to evaporate, or even run into the rivers with the resulting danger of fire. Now all is changed, and the utmost effort of the chemist and engineer is called for to devise means of increasing the yield of this despised by-product at the expense of the higher boiling fractions in the crude oil. The Government takes part in the research to meet the situation, and even legislation is asked for to assist in regulating the supply and demand.

Chlorine produced in this country entirely by electrolytic processes and with Niagara Falls as the center of the industry, offers another example of an originally annoying by-product becoming a necessity.

It is no flight of fancy to say that our lives and the lives of our families in Niagara Falls, Buffalo and over one thousand other cities, depend on the use of either liquid chlorine or chlorine in the form of "bleaching powder" or hypochlorite for the sterilization of our water supplies to a point where epidemics of typhoid are avoided. Niagara Falls, now free from typhoid, was a plague spot, nothing less, until we improved our filter system and treated the water with hypochlorite or chlorine. Our own army is using the same chlorine treatment to avoid the dangers from typhoid, which beset our soldiers during the Spanish-American war. In Europe the best preventative of blood poisoning and infection from dirty wounds is reported to be a mixture prepared from "chloride of lime" or bleaching powder. Without this same bleaching powder, our mills and printing establishments turning out or using book paper and writing paper could not turn out their product; our cotton dresses and sheeting would no longer be white; our shirts and collars from the laundry would be a dirty yellow; and, what is worse, a serious menace to health would result through lack of disinfection. Also, white cotton batting, bleached shellac, chloroform for surgical operations, even the disinfection of our garbage and sinks, call for chlorine in the form of "bleach." This same chlorine is used for the production of carbon tetrachloride, which in the form of "pyrene" has become a household necessity as a fire extinguisher.

To meet the shortage in coal-tar dyes, by the combination of chlorine with coal-tar benzol and toluol, we are now beginning to produce in quantity those necessary "intermediates" formerly made in Germany, from which are made sulphur black, picric acid, benzoic acid, trinitrotoluol, benzaldehyde or "oil of bitter almonds," and dozens of other products of like nature for which we are beginning to feel such urgent need.

Side by side with the production of electrolytic chlorine, we have caustic soda and caustic potash, resulting from the same electrolysis of either sodium chloride or potassium chloride. Caustic soda and caustic potash are equally indispensable in our daily economy. The amount of soap used per capita is said to make the state of civilization of a people. Without these alkalis we cannot make soap, and it is equally important for the production of mercerized cotton, refining of oils, the manufacture of dyes, explosives, pigments, and many chemicals and medicines, the cleaning of metals for electroplating, and the small can of household lye with its dozens of uses.

At several of the plants at Niagara Falls the electrolysis of chloride solutions takes place in cells where the products are directly united to form chlorate of

potash or chlorate of soda. Every match we strike, every primer for a rifle cartridge, contains chlorate. Also, it is a necessity for certain dyes and colors, and we may even use it in our tooth wash or as a lozenge for a sore throat.

A reference to the by-product stage of chlorine is perhaps of interest. The great heavy chemical industry of England developed from the acid and soda plants using the Leblanc process for the manufacture of alkali. The principal product sought for was soda ash obtained by decomposing salt, and the chlorine, driven off in the form of hydrochloric acid, was produced, as the industry grew, far in excess of any demand. As a by-product, this was allowed to escape from the chimney top, to the detriment of surrounding vegetation, or it was run into the rivers where it destroyed the fish, until the authorities called for some means of abating this nuisance. It was then that the hydrochloric acid was treated with manganese, and the free chlorine in turn absorbed by lime to form "bleach." As this chlorine was considered a valueless by-product, all that was considered necessary was to create a market which would perhaps pay for the lime, package and handling, and the early price for this by-product "bleach" was therefore very low. Gradually, however, a demand for the product was created, and a new industry, the bleaching of cotton and wood pulp, came into existence.

At this time, the Solvay process for the manufacture of soda ash was developed; a process which was able to produce soda ash and leave the chlorine in a harmless form as calcium chloride, and at the same time produce this soda ash at a much lower price than had been charged by the old Leblanc process. The old process had found a very satisfactory profit selling soda ash at \$60 per ton, and "chloride of lime" at perhaps \$12 per ton. When the Solvay people began to offer soda ash at \$30 to \$40 a ton, the Leblanc plants were unable to compete, and one after the other began to close down. To whatever extent this closing down took place, there developed a shortage of bleaching powder and muriatic acid, and in a very short time the price of bleaching powder was increased, owing to this demand and shortage, from \$12 a ton up to \$40 or \$50 a ton. The result was that the Leblanc plants were able to compete with the Solvay plants and reduce their price of soda ash accordingly, so long as they were able to obtain the higher prices for bleaching powder which now, of course, became their principal product and not a by-product, and caustic soda a secondary product. Again the pendulum has swung and we have chlorine as the principal but limiting factor around which the electrolytic production of caustic and chlorine products is built.

Turning again to the electrolytic products of soda at Niagara, we find the production of metallic sodium taking an important place. This forms the basis for the manufacture of the sodium cyanide supply of the country, and without this many of our most important gold and silver mines would be compelled to shut down, to say nothing of the great plants dependent upon the use of cyanide in electroplating. This same sodium is the basis again for sodium peroxide, used by the analyst as a means of determining fuel values, and as a means of generating oxygen for laboratory use, or in hospitals, and in submarines and mine rescue apparatus for preserving the breath of life. It is also used for the manufacture of hydrogen peroxide, used not only for bleaching purposes but also entering so freely into our daily lives as a simple household disinfectant.

Another electrochemical industry which has its chief center in Niagara Falls is the production of phosphorus. While yellow phosphorus is no longer used in the manu-

facture of matches, the sesqui-sulphide is an essential ingredient in the "strike-anywhere" match, and amorphous phosphorus in the safety match. Whenever you strike a match (not made in Sweden) think of chlorates and phosphorus made by Niagara power, and contemplate the possibility of a general return to the use of the flint and steel of our grandfathers' time, should these industries be expatriated (to Norway for example) for cheap power, and an embargo like the present one exist. Phosphorus also finds an important and irreplaceable use in the metal industry as a de-oxidizer and hardener in certain nonferrous alloys, chiefly in the phosphorizing of copper for the manufacture of phosphor bronze, used on battleships and for certain bearings on machines, automobiles and some chemical apparatus.

To sum up it will be seen that a large number of our most important manufactures and products of the utmost importance to the country are directly dependent upon the electrochemical industry at Niagara Falls. Among these we find the paper mills, soap factories, gold mines, the manufacture of chloroform, disinfectants, matches, explosives and dyes, water purification, cotton finishing, oil purification, and a dozen other activities which would be seriously hampered or closed entirely without the chemicals electrolytically produced at Niagara.

Permanent chemical self-containedness and preparedness to keep pace with this country's growing needs and population calls of necessity for an increase in the production of these plants. This increase cannot take place without an increased power consumption. The needed power stands ready for development without injuring in the slightest degree the scenic beauty of the Falls. The skill, energy and ability to utilize this power for the needs of the country are at hand. Only a maudlin sentimentality, not based on fact, stands in the way of a greater development and infinite gain to the country.

We have already noted the fact that some of the coal-tar "intermediates" so much needed for the manufacture of dyes, explosives and medicinal preparations, are now being made at Niagara Falls. As a rule these products need nitrogen to complete the product—nitric acid or ammonia—and this can be obtained by the fixation of atmospheric nitrogen by means of cheap electric power. The same fixed nitrogen is of equal importance to the agricultural interests of the country. The art is well started, but still in its infancy, and tremendous advantages to the entire country must ultimately accrue from the solution of the cheap fixation of nitrogen.

Let me close by repeating what I said in New York in February at a local section meeting:

"As this was written, I saw from my window the waters of the Niagara River flowing by with a capability of being developed into perhaps 5,000,000 hp.—the most uniform and constant water power in the world. I am very fond of the impressive beauty of its mighty Falls and the wonderful gorge and rapids below, and only as a last resort in the event of a national defense necessity would I do anything to injure that landscape. Such injury, however, is not necessary. As I study the daily moods of the Falls, I see the ebb and flow of water due to the direction and velocity of the wind on Lake Erie, making far greater differences in the volume of water passing over the brink of the Falls than is caused by the present diversion of water producing some 500,000 hp. I also see that the beauty of the Falls is not at its best when the largest volume of water is passing over its brink. From careful study I am satisfied that well over 1,000,000 hp. more could be diverted, and not an iota of injury would be done to the scenic grandeur of the Cataract if a little engineering skill were used in placing the proper breaks and deflectors. If this is true, think of the tremendous increase in national efficiency and preparedness this development would mean! Arrange now with Canada for a

development of water power at Niagara three times as great as at present—the time is ripe.

"For every 100,000 hp. diverted, provide say 10,000 hp. shall be devoted to the fixation of atmospheric nitrogen. The more varied the methods used the better. *Make Niagara the commercial research laboratory of the nation* in this field by supplying private enterprise with power at nominal cost for this purpose. Under these conditions, power, even if developed by private enterprise in large amounts, could in the above percentage be supplied as cheaply if need be as Norwegian power, and would be infinitely better adapted and centralized for the purpose. Such power would be within a night's ride of Washington, New York or Chicago. Already located at Niagara Falls is the largest group of electrochemical workers in the world. Such a development would double their number.

"Is it through lack of foresight, or 'a dog in the manger policy' that some of our largest and most important electrochemical industries are even now compelled through lack of cheap power to go to Norway and other fields, there to start the training of a foreign army of electrochemical workers upon foreign soil, while unused water which could be utilized without injury goes to waste?"

"I have been told that the Niagara River is a border stream; that plants situated near that border would be peculiarly open to foreign attack. Conceding that England be our enemy this is true. But did Germany give heed to an even stronger reason against making her experimental and peaceful development in Norway, where, as at Niagara, the economic conditions were right?"

"Not in a day, a month, nor a year can these problems, alike of peace and war, be worked out, the equipment developed and installed, and above all the workers trained. The goal is an ever-increasing internal independence both as regards food and chemicals. For an increasing population, this may well mean the regeneration of a worn-out soil, the re-fertilization of our farm lands from New England to the West with ammonia and nitrates from the air."

* * *

IV. The Nitrogen Industry

BY W. S. LANDIS.

The commercial fixation of atmospheric nitrogen has developed along three distinct and independent lines—the absorption by carbides, as exemplified in the present cyanamid process; the direct oxidation to oxides of nitrogen with subsequent formation of nitric acid, as represented by the arc processes; and the direct combination with hydrogen to form ammonia, as developed in the Haber process. Chronologically these three processes were developed in the order given above.

The original work of Frank and Caro, antedating the cyanamid process, started about 1895. The organization controlling the present industry was not formed until 1904, in which year we might really date the first beginnings of the commercial application. In 1906 the first factory was completed and began manufacturing on a considerable scale, but progress was slow until 1910 when the industry received a new impetus and production began simultaneously in various parts of the world. It was in this year, 1910, that steady production began at Niagara Falls, Canada, that plant having been completed late in 1909.

We are all familiar with the work done by Bradley and Lovejoy at Niagara in 1902, and while this initial installation did not prove the foundation of a commercial development, it directed attention to the arc process, and may be said to mark the beginnings of this great branch of the industry. In this same year, 1902, Birkeland and Eyde began taking out their patents, followed by the development of the great Norwegian plants. The following brief tabulation shows the growth of this industry in its early period:

Year.	H.P. Used
1902	3
1903	150
1904	1,000
1905	2,500
1907	40,000
1911	55,000

In 1905 the Badische Company erected a small experimental factory in Norway for the development of Dr.

Schönherr's arc furnace, which factory was enlarged in 1907. In that year it was using about 1400 kw. Later the Schönherr and Eyde processes were taken over by a new company, and the two furnaces have been operated side by side in the same factory. New installations at present going into operation will not employ the Schönherr furnace, so that the Norwegian developments will probably in the future all be directed to the use of the Birkeland-Eyde furnaces and process.

In 1906 the Paulings began experimenting with a new type of arc furnace for the oxidation of nitrogen, and in 1909 a commercial plant was erected at Innsbruck. This initial factory used approximately 15,000 hp. and was followed a year or so later by a 10,000 hp. plant in Italy, and a 25,000 hp. plant in France.

The Pauling process, however, has never attained very marked development for various reasons, and a small plant erected some years ago in this country has passed through a somewhat precarious existence, and will probably sooner or later be abandoned because existing conditions are not favorable to its commercial development.

The third and last of our processes for the synthetic production of ammonia has been in the hands of the scientist for many years. About 1905 the first promise of success appeared in the publications of Professor Haber, though no actual commercial progress was made in the matter until 1909 and 1910, when patents began to appear covering suitable catalytic agents. This process came under the control of the Badische Company, who spent several years of active development on it, and it was not until 1913 that commercial production was assumed. In 1913 and 1914 synthetic ammonia was produced on a fair scale by the Badische Company, but the process itself has not found a place outside of Germany, though attempts were made to introduce it into this country as late as 1914.

Recent developments in the nitrogen fixation industry have been on a scale unheard of in the world's history. Installed capacity for nitrogen fixation, expressed in short tons nitrogen per year, in 1913 and at the beginning of 1916, throughout the world are shown below:

	Short Tons Nitrogen Per Year	
	1913	1916
Cyanamid	65,590	209,510
Arc processes	18,650	29,400
Synthetic ammonia processes	8,000	60,000
Total	92,240	298,910

As most of this increase was made in 1915, we note that in practically one year the industry showed an increase of more than 200 per cent. One million horsepower is now consumed in the three groups of processes enumerated above.

The arc process up to the outbreak of the war did not find a secure place outside of Norway. Germany has erected only one new small plant (15,000 hp.). The Haber process still rests in the hands of the original developers in Germany, and no successful attempts have been made to transplant it from its place of origin. The cyanamid process has now large plants scattered throughout the world in Norway, Sweden, France, Italy, Germany, Austria, Switzerland, Japan and Canada.

Turning to another phase of the subject we find that these nitrogen fixation processes all require electric power for their operation. The arc process produces nitric acid directly, and uses nearly 3 hp. years of electrical energy per ton of HNO₃ produced, with small quantities of miscellaneous raw materials entering largely into recoveries of waste and the production of by-products.

The Haber process, whose sole product is ammonia, uses considerable quantities of energy, though little is heard of this phase of the process—fully half the requirements of a well-conducted cyanamid plant. In

addition it uses much fuel, and a large amount of highly skilled labor, so that careful investigations have proved that this process will with difficulty find satisfactory competitive fields outside of its country of origin.

The cyanamid process primarily produces cyanamid, a material which finds application directly as a fertilizer, or as a raw material for the production of many organic derivatives. It is a simple matter to transform the nitrogen in the cyanamid into ammonia, which finds further uses as ammonia liquor, anhydrous ammonia, a chemical reagent in itself, or as a commercial fertilizer directly in the form of either ammonium phosphate or ammonium sulphate. Further, it is commercially possible to oxidize this pure ammonia into nitric acid at high efficiency, and with the consumption of a negligible amount of electric power. Assuming, for the sake of comparison, that the end product of the cyanamid process is nitric acid, the power consumption required for fixing a unit of nitrogen by this process is only one-fifth to one-sixth that of the arc process. It is true that the cyanamid process uses raw materials in the form of lime and coke, but in this country these are extremely cheap and plentiful, and their cost is many times counterbalanced by the extremely great saving in power incident to the use of this process. Outside of a few skilled mechanics and electricians all the labor required may be of the most ordinary grade, and no trouble has been experienced along this line in the transplanting of this industry to the many countries represented. Nitrogen products, whether in the form of nitrates or ammoniates, can be more cheaply produced by the cyanamid process than they are otherwise securable, and this, so far as Germany is concerned, has not only been appreciated, but has been acted upon until she has by the development of the fixation of atmospheric nitrogen, chiefly the cyanamid process, made herself completely independent of all outside sources of nitrogenous materials.

None of the three main nitrogenous fixation processes has found a place within the borders of the United States. On account of the excessive power requirements of the arc processes the author is of the opinion that no serious thought has existed as to its adaptability to conditions in the United States, for cheap water power in sufficient quantity is not available in such districts as would enable the nitric acid made to compete with present sources, and as an emergency measure for munitions manufacture there is not sufficient power available to operate a plant of the necessary size.

It has been estimated by our military boards that in the event of war this country would need 180,000 tons of concentrated nitric acid per year. The arc processes in their present state of development could furnish this requirement with the expenditure of approximately 540,000 hp.—20 per cent more than is developed on both sides of the boundary line at Niagara Falls, the largest of our water powers. The cyanamid process could meet this emergency requirement with only 100,000 hp.

One attempt was made to introduce the Haber process into the United States, but abandoned after mature consideration, because of the impracticability of this process competing with others as a source of ammonia in this country.

Active attempts were made several years ago to bring the cyanamid industry into the Southern States, but the policy of the Government with respect to water power absolutely prevented development at that time. Since then the serious handicap of the higher power costs in the United States has discouraged further efforts to establish this industry in the United States. Successive additions which should have been erected in

the States were built to the Canadian factory where cheaper power was available.

Water power in the United States is expensive, not only because of the physical conditions which surround available water power sites, but also from the fact that hydro-electric power at practicable sites for its generation, even though it may be cheaply developed, has when developed an actual or potential value considerably in excess of what the nitrogen industry can afford to pay. Furthermore, there is a tendency for the law makers and others to view the value of water power to a community as measured solely by the price which can be secured for it from the individual customer using it for electric lights, small motors, street cars and other municipal purposes. Now a great water power converted to municipal use for the most part is of little, if any, economic importance. The difference in the cost of a kilowatt-hour of energy on the switchboard generated by steam, as compared with a kilowatt-hour of energy developed by water, is part of a cent. Under the usual conditions of a water-power site being remote from the communities in which the power is used, the difference in cost between the power generated in the community by steam, and the power generated by water and transmitted to the community, is a bare fraction of a cent. The price of power delivered to the consumer under these conditions averages, generally speaking, 6 cents per kw.-hr., namely, from 2 cents for large users up to 12 cents for the small users. Estimates of the saving in the use of water power as compared with steam show by specific examples that even if the customers benefited to the extent of the entire saving, the advantage to the customer would not amount to more than 4 to 5 per cent of his monthly bill.

We have just reviewed the history of the nitrogen industry, and noted that it has found no place in the United States. We have further seen that cheap water power is a necessity of the industry, and that our policy of water-power development has not produced, nor is it tending to, such cheapening of electrical energy as is needed to make a place for this industry. The cost of this policy, as pertaining only to this one industry, to the people of the United States may be gained from the following figures:

The import invoice value (port values less freight) of nitrate of soda and sulphate of ammonia brought into this country between the years 1910 and 1914, a period during which there have existed successful, commercial, operating nitrogen fixation plants elsewhere, amounted to \$108,323,568, or an average of approximately \$22,000,000 per year, all of which has actually been paid out to foreign producers of these materials—money which has actually left the country.

This tonnage was probably brought to the United States in foreign vessels, thereby adding the freight charge, or nearly \$4,000,000 per annum to the above, and making a total of \$25,000,000 per annum paid to our foreign business friends, who are not hampered by such difficulties as have existed in the United States. One hundred and fifty thousand continuous horsepower would fix this amount of nitrogen and under favorable power rates at a materially lower cost than the import invoice values quoted above.

Within the last few months this nation has been aroused to at least some little sense of the necessity for preparedness for national defense in case of war, and there is thus brought into the nitrogen problem quite a new element, particularly so far as the necessity for immediate development is concerned. The most important new thing in the method of conducting a war is the very greatly increased consumption of explosives. Save in the fixation of atmospheric nitrogen there is only

one source from which nitric acid can be secured, namely, from Chilean saltpeter, and nitric acid is the universal prerequisite to the manufacture of military explosives.

For this purpose alone it is estimated that Germany is consuming to-day at the rate of practically 1000 tons per day. Germany found from her experience in the present war what the United States should anticipate would be its fate, namely, that in any war with a stronger maritime nation the supply of Chilean nitrate would be cut off. These are the considerations in part which point to the absolute necessity for the establishment within the borders of the United States of the air nitrogen industry. The difficulty, however, is to make the undertaking securely profitable in times of peace, chiefly because the cost of power within the States is excessive as compared with the cost of it in other countries, and power in all of the commercially practicable processes is the chief item of expense in manufacture.

Is it not a logical conclusion from the above facts that the great economic use of water power is in applying it to those industries which produce a material entering into the fundamental necessities of the people, either directly or as raw materials for a succession of other refinements? One of the striking characteristics of water power is that it frequently furnishes the one and only necessary means by which new and valuable industries can be introduced and make commercially practicable. Thereby water power is properly to be credited with giving birth to the industry, and the importance of the water power under these conditions is to be measured by the fact that this industry in its turn gives new employment, not otherwise to have been had, to hundreds, and perhaps thousands, of workmen; the product in turn in its other refinements and applications gives employment to hundreds, and perhaps thousands of additional hands; and so on indefinitely. If the product is one which makes for the amelioration of the most pressing of all the modern-day evils, namely, the continually increasing cost of living, the use of the water power in this production is the very highest economic use to which it can be put. This is precisely what water power applied to the fixation of atmospheric nitrogen does for the world, for the chief use of the product is as an agricultural fertilizer. The secret of cheaper food can only come through increased crop yield per acre cultivated without the employment of additional farm labor, and the only means to this end is a cheap and plentiful supply of artificial fertilizers.

The importance of labor-saving devices is so well recognized, and so universally accepted in the equipment of factories and mines, that it is all the more unusual that the people of the United States and the Government have not realized that in the field where the disproportion of wages between the European worker and

the American worker is greater than anywhere else, adoption of the greatest of all labor-saving devices, namely, agricultural fertilizers, has not only failed to become universal, but has not been carried out at all except on the most meager scale.

The Conifer Leaf Oil Industry

BY A. W. SCHORGER

Chemist in Forest Products

The production of oils from the leaves or needles of various conifers is a small but fairly old industry in the United States. According to the best estimates obtainable, the value of the oils produced annually from this source amounts to approximately \$50,000. The leaves of only a few species of conifers are regularly distilled for their oils, since it is only for these oils that a steady demand has been created.

The principal species employed are the black spruce (*Picea mariana*, Mill.), white spruce (*Picea canadensis*, Mill.), eastern hemlock (*Tsuga canadensis*, Linn.), red juniper (*Juniperus virginiana*, Linn.), and arbor vitae (*Thuja Occidentalis*, Linn.). The oils of white spruce, black spruce, and hemlock are very similar in composition. No attempt appears to be made to keep the leaves of the latter species separate, and for practical purposes a distinction between them seems unnecessary.

The annual consumption of spruce and hemlock oil is estimated at 40,000 to 50,000 lb. It is quoted at \$0.45 to \$0.60 per pound. The leaf oil of the red juniper is used largely in insecticides, the annual consumption being 15,000 to 20,000 lb. The prices of the oils from the various native conifers are approximately the same as that given above. The oil of *Pinus picea*, imported from Europe, is sold at about \$4 per pound, but the annual demand is below 50 lb.

YIELDS OF OIL FROM VARIOUS SPECIES

The oil is found in longitudinal ducts running through needles. The number and size of the oil ducts vary greatly with the different species, and on these factors the yield of oil is largely dependent. The number of oil ducts may vary from one to ten. Naturally the species containing numerous ducts of large size will give the largest yield of oil. This assumption has been verified in the various species examined.

Figs. 1 and 2 will serve as illustrations. The long leaf pine needle contains five large oil ducts, the average yield of oil being 0.42 per cent, while the lodgepole pine needle contains two oil ducts, the average yield of oil being only 0.16 per cent. In all cases the yields are given in per cent of the weight of the green leaves.

The approximate yields and principal constituents of the various species are given in Table I.

TABLE I

	Yield of Oil	Sp. Gr.†	Principal Constituents
Red pine (<i>P. resinosa</i>).....	0.10	0.8610	α-pinene
Pitch pine (<i>P. rigida</i>).....	0.10	0.8610	Camphene, β-pinene, borneol, cadinene
White pine (<i>P. strobus</i>).....	0.10	0.9012	α-pinene, β-pinene, borneol, cadinene
*Longleaf pine (<i>P. palustris</i>).....	0.40	0.8829-0.8849	α-pinene, dipentene, borneol
*Cuban pine (<i>P. heterophylla</i>).....	0.57	0.8877-0.8894	α-pinene, dipentene, borneol
*Western yellow pine (<i>P. ponderosa</i>).....	0.08	0.8718-0.8849	α-pinene, β-pinene, limonene, borneol
*Sugar pine (<i>P. lambertiana</i>).....	0.09	0.8676-0.8738	α-pinene, β-pinene, limonene, borneol
*Digger pine (<i>P. sabiniana</i>).....	0.09	0.8517-0.8566	Phellandrene, β-pinene
*Lodgepole pine (<i>P. contorta</i>).....	0.23	0.8690	Phellandrene, β-pinene, borneol
*Red fir (<i>Abies magnifica</i>).....	0.15	0.8665	α-pinene, β-pinene, phellandrene, borneol
*White fir (<i>Abies concolor</i>).....	0.13	0.8720-0.8777	α-pinene, β-pinene, limonene, borneol
*Douglas fir (<i>Pseudotsuga taxifolia</i>).....	0.16	0.8727-0.8759	α-pinene, β-pinene, limonene, borneol
Red spruce (<i>Picea rubens</i>).....	0.20	0.9539 at 16 deg.	Borneol, bornyl acetate
Black spruce (<i>Picea mariana</i>).....	0.60	0.9274 at 19 deg.	Bornyl acetate, terpenes
White spruce (<i>Picea canadensis</i>).....	0.10	0.9218 at 20 deg.	Bornyl acetate, limonene (?)
Hemlock (<i>Tsuga canadensis</i>).....	0.40	0.9288 at 20 deg.	α-pinene, bornyl acetate
Balsam fir (<i>Abies balsamea</i>) Miller.....	0.50	0.8881 at 20 deg.	α-pinene, bornyl acetate
White cedar (<i>Thuja occidentalis</i>).....	0.50	0.915-0.930	α-pinene, fenchone, thujone, borneol
Western red cedar (<i>T. plicata</i>).....	1.00	0.9305 at 25 deg.	Thujone, pinene
*Incense cedar (<i>Lib. decurrens</i>).....	0.23	0.8655-0.8733	α-pinene, limonene, borneol, lincodrene
Red juniper (<i>Juniperus virginiana</i>).....	0.20	0.887-0.900	α-pinene, limonene, borneol, cadinene
Tamarack (<i>Larix laricina</i>).....	0.15	0.8816	α-pinene, bornyl acetate

*Examined by author. †At 15 deg. unless otherwise stated.

PROPERTIES, COMPOSITION AND USES

As a general rule the oils have a pleasant odor, resembling the fragrance of coniferous forests. Occasionally the freshly distilled oils have a disagreeable odor that frequently improves with age.

The oils are composed mainly of terpenes, terpene alcohols and their esters, and sesquiterpenes. (See Table I.) Among the terpenes, pinene and limonene are ordinarily present. The attractive odor of the oils is due mainly to borneol and its acetic ester. In general, the more highly prized oils contain large amounts of borneol, both free and combined. Spruce and hemlock oil contains 35 to 50 per cent of these constituents. The popular Siberian needle oil, of which 5000 to 10,000 lb. are imported, contains from 29 to 39 per cent bornyl acetate. Among the sesquiterpenes cadinene occurs most commonly. Thujone is a characteristic constituent of thuja oil from *Thuja plicata* and *Thuja occidentalis*.

It is difficult to obtain direct information on the purposes for which the various oils are employed. A large amount of correspondence addressed to manufacturers purported to use these oils in their products afforded very little information. Information on the uses to which the oils are put was obtained mainly from dealers and distillers of the oil.

The spruce and hemlock oils are extensively employed as a perfume in greases and shoe blackenings. It is also used in considerable quantities in liniments and other medicinal preparations.

Cedar oil from *Juniperus virginiana* is employed mainly in insecticides. Thuja oil from *Thuja occiden-*

talis is used in insecticides and liniments. Various native and foreign oils are employed medicinally, as inhalations for lung diseases, and as additions to baths and ointments in rheumatic afflictions. Various perfumes contain certain amounts of needle oils whose value consists in having a so-called "ozonizing" effect. The oil of *Pinus montana* mixed with chloroform is used in quantity as an embrocation. In Europe, especially, the finer needle oils are used extensively as perfumes in soaps.

DISTILLERS OF OIL

The greater portion of the oil is distilled by small farmers in New England during the winter months when the farm work is slack. In 1912 a company in Seattle, Wash., was engaged in the distillation of the leaf oil of red cedar (*Thuja plicata*) on an extensive scale. The branches, $\frac{3}{4}$ in. or less in diameter, were delivered in Seattle in bundles of 100 lb. at a contract price of \$4.50 to \$5.50 per ton, depending on their oil content. The material was packed in the stills and distilled with steam at a pressure of 40 to 90 lb. for three

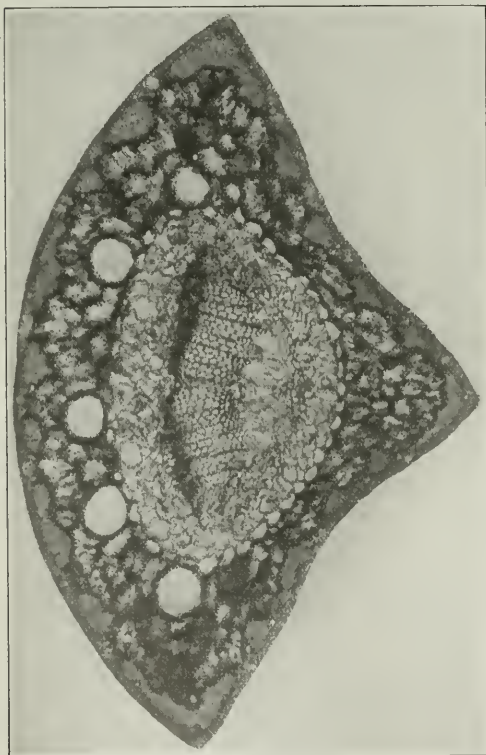


FIG. 1—CROSS-SECTION OF NEEDLE OF LONG LEAF PINE (*PINUS PALUSTRIS*); 5 LARGE OIL DUCTS; YIELD OF OIL 0.4%

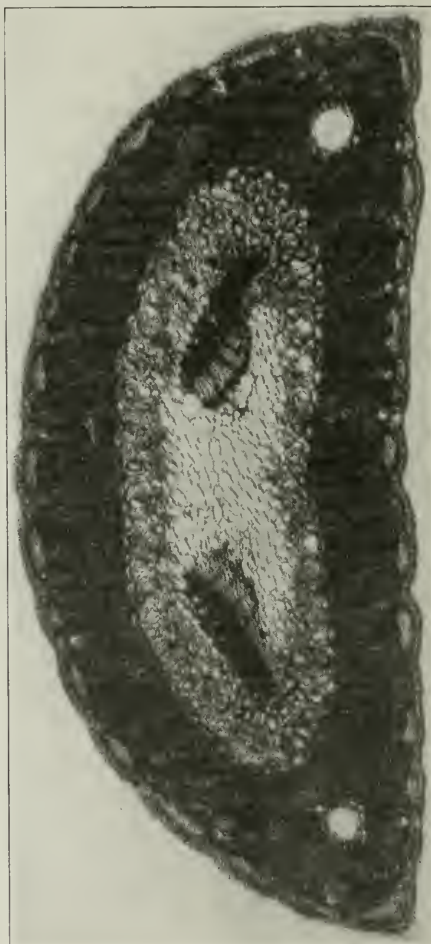


FIG. 2—CROSS SECTION OF NEEDLE OF LODGE POLE PINE (*PINUS CONTORTA*); 2 OIL DUCTS; YIELD OF OIL 0.16%



FIG. 3—STILL AND CONDENSER



FIG. 4—RECEIVER WITH THIN LAYER OF OIL

to five hours, the distillation being discontinued when the amount of oil coming over did not exceed 10 c.c. in five minutes.

The average yield of oil was about 1 per cent of the weight of the green material. Young trees contained the largest amount of oil, and the leaves were richest in January, February and March. The oil had a market value of \$0.40 per pound, but this was scarcely sufficient to cover the cost of production. Most of the oil was employed in the manufacture of an insecticide called "Mothine." This was a dry powder containing about 35 per cent of cedar oil and 65 per cent of an absorbent made by nitrating the finely ground shells of peach pits.

Attempts have been made at various times to utilize pine needles for the production of fiber after the oil had been removed by distillation. The most ambitious attempts in this direction were made by C. M. and O. C. Terrell of Grants Pass, Ore., who obtained patents Nos. 675,206 and 758,874, covering methods and apparatus. The plant, described by Brown,* utilized leaves systematically picked from young trees of the Western yellow pine. The stills consisted of wooden tanks with steam connections, and had a daily capacity of 2000 lb., from which 10 lb. of oil were obtained. After suitable treatment the spent needles produced a long, tough fiber that could be woven into fabrics or made into mattresses when mixed with hair.

FOREST SERVICE INVESTIGATIONS

The large amount of lumber cut from coniferous woods renders available large quantities of needles and twigs that at the present time are not only a sheer waste, but are frequently the cause of destructive forest fires. If a sufficient market could be created for the oils a great economic advance in management would be effected. At present, however, the demand and price

for oils of this type do not warrant their manufacture on a large scale.

The leaves of a number of the most important Western and Southern conifers were distilled to determine the yield and chemical composition of the oil. Samples of these oils were sent to various manufacturers for practical tests. The most promising oils, judged from odor, were those of longleaf pine and Western yellow pine. Unfortunately in nearly all the oils the ester content was low and their odors did not surpass those of the already firmly established spruce and hemlock oils. There appears to be an increasing utilization of conifer leaf oils, and the creation of a demand for new oils, as well as the extension of markets for the common ones, may be anticipated. It is frequently difficult, however, to introduce a new oil on the market, even though it may have decided merit.

PRINCIPLES OF DISTILLATION

The oil is removed from the leaves by the familiar method of steam distillation, usually at atmospheric pressure. As the steam passes upward through the needles the oil volatilizes and the mixed vapors pass together into a cooling apparatus, where condensation takes place. The condensation products soon separate into a layer of oil and water, owing to their immiscibility and difference in specific gravity.

FACTORS INFLUENCING YIELD OF OIL

Steam distillation under pressure is more rapid and produces more oil than distillation at ordinary pressure. When steam at atmospheric pressure is employed a greater yield is obtained if the needles are cut into small pieces. In this way the oil ducts are more exposed to the action of the steam and more material can be placed in the still. Experiments have shown that a still will hold 25 to 50 per cent more material when it is finely cut.

**Sci. Am.*—81, 344 (1901).

The largest yields are obtained from young trees. In New England cedar oil is distilled almost entirely from small trees growing in old pastures and abandoned fields. All trees growing in the open contain more oil than those in a normal forest stand. The season of the year also appears to have a considerable effect, the data available essentially agreeing in that the most oil is obtained during the winter and spring months. The leaves of the Western red cedar (*Thuja plicata*) were richest in January, February and March; the leaves of incense cedar were richer in February and November than during the intervening summer months.

THE STILL AND ITS OPERATION

The experimental still used by the Forest Service is shown in Fig. 3. The still proper was constructed in three parts. The cylindrical body of the still for holding the needles was 3 ft. 6 in. in height by 2 ft. 3 in. in diameter, and was made of 16 B. W. G. copper. The ends were flanged out and provided with iron rings $1\frac{3}{4}$ in. wide. The cover of the still and the top of the heating vessel were similarly flanged and provided with rings. The cover and base were fastened to the cylinder with malleable iron clamps.

In order to support the needles the inner base of the cylinder was provided with lugs upon which rested a removable frame covered with 20-mesh No. 25 B. W. G. brass wire. The exterior of the still was covered with several layers of asbestos in order to reduce radiation of heat and condensation of the vapors.

The heating vessel containing the water was 3 ft. in diameter and 2 ft. 1 in. high, and was constructed of 11-gage copper. This vessel was provided with a $\frac{1}{2}$ -in. water gage and a funnel attached to a hand lever stop for introducing water when necessary.

The condenser consisted of 20 ft. of $1\frac{1}{4}$ -in. copper tubing wound in a coil of $1\frac{1}{2}$ ft. internal diameter, placed in a galvanized iron tank 2 ft. in diameter by $2\frac{1}{2}$ ft. deep. The condenser was connected to the still with an 8-ft. copper pipe, in two sections, 2 in. in diameter.

A 2-gal. aspirator bottle (Fig. 4), having a brass siphon, served as a receiver.

The material to be distilled was first passed through a feed cutter, the needles and twigs being cut into lengths of $\frac{1}{2}$ to 1 in. When the chopped material was well packed into the still the charge varied from 350 to 500 lb., depending upon the species. By filling the cylinder ahead of the rising column of steam, the needles are decidedly more compressible.

The distillation was continued at the rate of $2\frac{1}{2}$ gal. per hour. At the end of seven to eight hours the quantity of oil fell to 5 to 6 c.c. per hour, and the distillation was then considered complete.

The oils are dried and filtered through cotton baton or fine muslin, and are then ready for market. Sometimes they are subsequently rectified by dealers.

The small distillers usually employ apparatus constructed partly of wood. The leaves are placed in rectangular or cylindrical wooden tanks, while steam is introduced from a separate generator. The simple apparatus used by a New England distiller of cedar leaf oil will serve as a type of the stills frequently employed. His description is the following: "A steam-tight box, 3 ft. by 4 ft. and $3\frac{1}{2}$ ft. deep, with a boiler-plate bottom, is set on a rock furnace. Inside of this box is a grating 4 in. above the bottom to hold the cedar up to the top of the grating; a pipe from the top of the box 10 ft. long carries off the steam. This steam pipe runs nearly its entire length through a trough of water kept cold by running water. The condensed steam drops into a glass jar covered with cloth for a strainer."

Forest Products Laboratory,
Madison, Wis.

Laboratories of Canadian Department of Mines

Bulletin No. 13, recently issued, of the Mines Branch of the Department of Mines, Canada, contains an interesting and nicely illustrated account of the extensive laboratories of the Mines Branch. Dr. Eugene Haanel is director of the Mines Branch.

The Department of Mines was created in 1907 by Parliament and at the outset it was found necessary to have some of the experimental work of the Mines Branch done at the laboratories of McGill University, Toronto University and Queens University until facilities could be provided at Ottawa.

The first of the new units for the proposed general laboratories and testing system, namely, the fuel testing station, with its laboratory for the analysis of mine air, natural and other combustible gases, oils, etc., and well equipped machine shop, was opened at southwest Ottawa, in 1910; and this was followed, in 1911, by the erection of an ore dressing and metallurgical laboratory, adjoining the fuel-testing station. Then, in 1912, came the combination and installation under one roof at the headquarters of the Mines Branch, Sussex Street, Ottawa, of the old Geological Survey and newer Mines Branch chemical laboratories; and to these was added, in 1915, a fully equipped section for the testing of the waters of Canada. In the same year a ceramic laboratory, completely equipped for testing the clays of the Dominion, was erected in the Mines Branch building also; together with a fully equipped laboratory for the testing of structural materials, cement, concrete, building stones and sands for concrete making, foundry purposes and glass manufacture. The latest addition is a metallographic laboratory for the preparation and micrographic examination of specimens of steel and alloys required for the practical work of the Metallurgical Division.

It is purposed, in the near future, to still further extend the scope of the technical work carried on in the various laboratories above mentioned, such as the testing of lime, road materials, paint mixtures, etc., and to provide suitable appliances and equipment for other lines of work which come under the statutory jurisdiction of the Mines Branch.

The chemical laboratories, which were established as part of the Geological Survey in 1843, have received such a large amount of work since being placed under the direction of the Mines Branch in 1907, that extensive alterations and additions became necessary. At the present time the laboratories are well equipped for the analysis and assaying of all kinds of rocks, minerals and ores. Numerous illustrations and plan views of the laboratories, together with full descriptions, are given in the bulletin.

The fuel testing station is equipped with commercial-size gas producers, large steam boiler, a 60-hp. gas engine, also fully equipped chemical and assay laboratories, and a well-equipped machine shop.

The ore dressing and metallurgical laboratory is very complete and the plant is equipped with large-sized apparatus as employed in actual practice as well as laboratory-type apparatus.

The ceramic, structural materials and metallographic laboratories are also well equipped.

The rapid rise of this series of technological laboratories has been due to the many demands made by the public for examination and testing of promising ores and minerals, to requests for the investigation of special subjects of commercial importance, and to experimentation along lines considered commercially important.

A Company That Makes the Most of Its Chemists

BY DANIEL T. PIERCE

The main entrance to the great refining and manufacturing plant of the Barber Asphalt Paving Company at Maurer, N. J., is through the laboratory building. This is symbolical of the place of authority that the company's chemists occupy in its organization—nothing can get into or out of this 256-acre plant without coming under the eye of the laboratory. Truth to say, the location of the laboratory building is fortuitous, for it did not always occupy its present high estate in the Barber company's affairs. Now, however, in the evolution of human affairs in general and the manipulation of bituminous materials in particular, the time has come when "the chemists run the company," and it is fitting as well as convenient that the front door of the plant should be the front door of the building that houses the technical staff.

The problems of the company are concerned with the refining and the adaptation to a great variety of uses of asphalts of every known variety, but mainly the native asphalts, Trinidad and Bermudez, gilsonite and grahamite. Although from its name the company might be supposed to be largely concerned with paving (as it was at one time), the larger part of its business is now the production of paving materials and asphaltic products for every purpose under the sun, from asphalt, crude, at one end of the alphabet, to waterproofing compounds at the other. Its record book of compounds (all formulated by its chemists) approaches the dimensions of an unabridged dictionary. In other words, the activities of the Barber company's chemists are not concerned merely with controlling straight runs of asphalt for paving purposes—they are charged with the duty of providing formulae for asphaltic compounds for a great variety of purposes, with meeting the demands of a dozen different industries—from shoe-making to copper leaching, and with full responsibility for seeing that the materials turned out by the manufacturing department are suitable for the purpose for which they are intended.

With so many ready-made formulae it might be supposed that the laboratory force could occasionally take a rest, but no week passes without bringing new problems for the chemists to solve. In addition to the demands for special purposes or for variations of standard formulae that are turned in by salesmen (many of whom are themselves graduate chemists), "scout chemists" are employed to seek out new applications for asphalt and to suggest improvements in industrial processes in which asphalt has perhaps been employed but not so well or effectively as it might be. This often necessitates investigation of manufacturing processes wholly remote from the asphalt business.

The routine may include the investigation of linoleum, driving belts, and the making of rubber articles, all with the purpose of adapting asphaltic materials for use or improved application in those industries. The demand may come from a copper smelter for an acid-proof mastic tank lining, from a shoe manufacturer for a compound for stiffening toe boxes, or from a cork manufacturer for an asphalt cement that will properly combine with a cork aggregate for making flooring blocks. Experimentation with the raw materials of these apparently unrelated lines is as much the business of the Barber laboratory as is the manipulation of its own products—providing such an investigation promises to enlarge the market for asphalt in some new form or to better a process in which asphalt is employed. This is the work of the industrial research division of the

laboratory, the other arm of this division being concerned with sampling and plant control in connection with the company's own manufacturing operations. It should perhaps be said at this point—although we are concerned here only with laboratory activities—that the Barber company in its own plants makes refined asphalts and cements of every kind, roofing, asphalt shingles, mastics, waterproofing compounds and fabrics, asphalt blocks, mineral rubber and other gilsonite products, protective paints, asphalt putty, expansion joints, etc.

Continuing with the organization of the laboratory and its work, the paving division is concerned with the control, regulation and improvement of paving mixtures and the materials that enter into them—asphalt, sand and stone. This division serves the company's own paving branches and contractors who use its materials. The chemical division has two branches, analytical and chemical research. The latter branch is under the direction of Clifford Richardson, with the title of consulting chemical engineer. The most important recent work of this branch of the laboratory has been the study of the colloidal content of Trinidad asphalt and the development of colloidal bituminous mixtures for various industrial purposes, such as battery jars, insulation, and other molded articles, etc. Branches of the main laboratory are located at Chicago, in order to be more closely in touch with paving operations in that territory, and at the Madison, Ill., manufacturing plant of the company. These with a clerical and record division complete the organization. With the exception of the research work directed by Mr. Richardson, the whole laboratory is directed by a chief chemist, C. N. Forrest, and an assistant chief, J. S. Miller, Jr. The chief chemist reports directly to the president of the company.

Consultation between the directors of the laboratory and the sales and manufacturing departments is constantly going on by letter, long-distance and local telephone, and by personal interviews. Not the least valuable service rendered by the company's chemists is the aid and advice thus given, although it is quite outside of what is usually conceived to be the chemist's function. And in addition the laboratory is a training school for salesmen and, if they desire it, for the employees of contractors who use the company's materials. It is constantly visited by students of chemistry and highway engineering, and not infrequently by the chemists and engineers of other manufacturing concerns or those connected with municipalities.

The question as to how and how completely this laboratory controls the manufacturing and producing operations of the company is best answered by following the routine of an "order to manufacture." When an order is sent to the manufacturing department, a carbon copy goes at the same time to the laboratory. This order contains a formula number or description of the product to be made, quantities, shipping directions, etc. The manager's office thereupon issues an order to manufacture to the appropriate department of the plant, a copy of which is also supplied to the laboratory. If the process of manufacture is at all complicated or involves a number of steps the plant supplies the laboratory with samples as the manufacture progresses. When the work is completed the plant asks the laboratory for an inspection and a final sample is taken by a laboratory employee. The taking of samples is not left to anyone engaged in manufacturing or compounding.

The conclusive factor in the control of the laboratory is that the plant cannot ship until the laboratory has approved the goods made. It receives a copy of the original order and knows what is required; it receives a copy of the order to manufacture and sees that that corresponds to the customer's order; finally, it inspects

the finished product and decides whether or not it meets the specifications. If it does not it cannot be shipped, for even after the sample of the completed product has been taken by the laboratory, the shipping department must advise the laboratory each day what order numbers it is proposed to ship. Approval of shipment must be given by the laboratory before the shipping department can go ahead. Ordinarily, to save time, permission to ship is given by telephone, but a written "confirmation of approval" must follow this as soon as possible.

It might be supposed that such a system as this would be productive of endless friction between the manufacturing and chemical staffs. But this is not the case. It may happen that a plant superintendent will occasionally think that the laboratory is unduly critical; perhaps they often think so. On the other hand, the manufacturing force is relieved of many troubles and practically all of the usual "kicks." For the laboratory is made responsible, and if a faulty shipment is made the laboratory is to blame. Its responsibility begins with the formulas it has devised or approved, and extends, as shown, to the point where shipment is ready to be made. In brief, the laboratory is the conscience of the company—the Supreme Court from whose decision there is no appeal.

Men of the chemical profession sometimes complain that their services are not appreciated and that they are made subordinate to non-technical superiors. In the case of the Barber company no such complaint can be made, for it is literally true that so far as the making of its products is concerned "the chemists run the company."

Philadelphia, Pa.

The Calculation of the Burden of the Blast Furnace

BY J. E. JOHNSON, JR.

Having set forth in the issue of April 15 the principles which control the variations of the various elements in the iron, and in the issue of April 1 the principles on which our slags must be based, we are now able to proceed to the details of calculating the burdens for a given case. This is a matter of which a great mystery has often been made, but in reality when the very simple principles are understood it is no more complicated than a sum in arithmetic.

It seems worth while here to go back once more and say that our knowledge of slags is a purely empirical knowledge. The scientist cannot sit down in his study and work out from the ultimate laws of chemistry, no matter how well he may know them, the slag which must be used or will give the best results in a given case. We only know as a result of countless thousands of trials and analyses, by our predecessors and ourselves, that certain ratios of fluxes to materials to be fluxed give the best results. These results I believe to be as set forth in the last chapter, that the alumina chemically is a matter of indifference, and that the ability of a slag to do the necessary desulphurization remains the same while the ratio of lime to silica remains the same, through a wide range of variations in the alumina, at the same time not forgetting that alumina exerts a powerful influence particularly, within a certain range, on the viscosity and the melting point of the slag, and therefore has a profound effect on the thermal equilibrium of the furnace.

We can go further and say that the ratio of lime to silica is itself almost a constant one for best results, varying from about 1.3 lime to 1 silica for foundry irons, to 1.5 lime to 1 silica on basic irons, Bessemer lying

between these two with a ratio of about 1.4 to 1.

Given these facts, and leaving out of consideration for the moment the phosphorus question, the calculation of a burden for given ores becomes very simple. We have only to calculate the amount of silica brought in with the charge and to be carried out as slag, and then determine the amount of limestone which will give us the necessary ratio of lime to silica in the slag for the kind of iron we desire to make.

There are, however, some precautions to be taken here. First of all, of course, is the fact that silica and alumina are brought in not only by the ore, but also, to some extent, by the fuel and the limestone, and that the amounts brought in by these must be taken care of exactly the same as that brought in by the ore. On the other hand, a fact of much importance in rich ores is that the silicon in the iron comes from the silica of the charge, and that, therefore, the quantity of silica to be fluxed is correspondingly reduced. Take for instance the case of a charcoal furnace with a 60 per cent ore carrying 5 per cent silica, and disregard for our present purpose the small amount of silica in the limestone and fuel. Counting 0.95 units of Fe for a unit of pig iron we should have silica present equal to 8 per cent of the weight of the iron, provided the iron produced were silicon-free, but if the iron contained 3 per cent silicon corresponding to $6\frac{1}{2}$ per cent silica we should only have left to pass out into the slag $1\frac{1}{2}$ per cent of silica instead of our original 8 per cent. The case taken is intentionally an extreme one, so as to drive home the fact that the apparently insignificant percentage of silicon in the iron requires careful consideration in burdening the furnace.

There are various means of simplifying burden calculations. The limestone practically always contains some silica, ordinarily from 1 to 6 per cent or 7 per cent; it is generally under 5 per cent, though I have known limestone containing 10 per cent silica to be used. Obviously, then, whenever we increase the limestone we increase the silica also, and this requires a further increase of stone. This would mean several corrections if we did not adopt some means to avoid this trouble; the proper one is to figure the efficiency of the flux and base the quantity required on this. From the percentage of line which it contains we deduct the amount necessary to flux the silica which it contains at the ratio desired for the given slag. For instance, if we have a certain stone containing 2 per cent silica, 2 per cent iron and alumina, 52 per cent $\text{CaO} + \text{MgO}$, the balance being CO_2 , which is driven off as the stone descends through the furnace, and if we desire a slag with a lime-silica ratio of 1.5 to 1, we deduct from the lime present 1.5×2 per cent = 3 per cent, leaving lime available for other silica 49 per cent, which is commonly called the "efficiency of the stone"; that is to say, every 100 lb. of stone contains 49 lb. of lime available for fluxing the silica of the ore and coke.

The Moisture in the Ore

It is customary practice to give the analysis of iron ore on the basis of its weight when dried at 212 deg. Fahr., and this is quite right and proper since there are variables enough with which to contend without our being uncertain as to the weight of moisture in the sample, but in figuring burdens for the furnace we do not have ores so dried, and it is very necessary to have moisture determinations made on samples of several pounds weight, so as to know the actual weights of the different materials the furnace is receiving for each thousand pounds of natural (undried) material charged.

The actual analysis of the ore must be calculated back from its dry weight and its actual moisture contents,

and the analysis so determined must be used in burden calculations. This is a matter of much importance, because the average moisture of the Lake Superior ores is probably nearly 11 per cent, and, of course, it would distort our calculations past all recognition if due allowance were not made for this fact.

In addition to this many ores contain what is known as combined water, or water of crystallization, which is not driven off until temperatures several hundred degrees above the boiling point are reached. This water is, however, given in the chemical analysis where it properly belongs, and is not as likely to cause confusion as is the free moisture of the ore.

Flue Dust Loss

We have here a factor varying widely with the practice, and one for which it is difficult and fortunately unnecessary in most cases to make allowance in advance. A decidedly appreciable percentage of the ore in furnaces using 30 per cent or more Mesabi is blown out the top of the furnace with the top gases. Some of it is recovered in the dust catcher, some in the gas washer, if there be one, and some goes out the stacks with the burnt gases leaving the stoves and boilers.

Mr. John N. Reese has made some very accurate determinations on this subject, and he has told me that he finds about 3 per cent of the total iron charged disappears in one way or another, a figure which other furnace men confirm.

Part of this goes out as the impalpable dust remaining in the combustion gases even after washing, and a part of it is lost in the slag, as described in the chapter on slag.

In spite of the losses of the iron chemically combined in the slag which in normal practice probably vary between two-tenths and six-tenths, the loss of iron in the slag in the metallic condition, and the loss of ore dust in the top gases, a furnace running under reasonably good conditions always produces more pig iron than the weight of the metallic iron charged, for the reason that pig iron contains seldom more than 95 per cent Fe, and generally less than that, there being generally about 4 per cent of carbon and seldom much less than 1 per cent of silicon, with generally from $\frac{1}{2}$ to 1 per cent of manganese, and from 1/10 up to 1 per cent of phosphorus.

The general practice in burdening furnaces is to adopt a constant charge of coke, and to keep this invariable, changing the ratio of coke to ore when necessary by altering the weight of the ore. This system has three advantages: First, a constant weight implies a constant volume and allows the weight of the coke charge to be checked against this volume, which is very desirable, because coke is capable of absorbing a large quantity of moisture, and if charged by weight alone when wet the charge of dry coke would be much too light. Second, there is one size of coke charge suited to the furnace, and while small variations in the size of no importance, it is desirable to have the charge constant at the most advantageous size. Third, the weight of coke being constant, and its analysis presumably so, it is a simple matter to figure out the slag-forming materials in the coke and calculate the quantity of stone necessary to take care of these. This, under these circumstances, becomes a constant quantity, and we do not have to complicate burden calculations by taking into account the slag-forming ingredients of the coke every time the burden is changed, but merely calculate the stone necessary for the ore, and add to this the constant quantity required by the coke.

When the ore contains no gangue but silica and alumina, the calculation of the burden is very simple.

We have only to add together the weights of silica in the different ores constituting the charge and figure the weight of limestone necessary to flux these. At the same time it is very desirable to keep track of the alumina, and after determining the amount of silica and lime-plus-magnesia to add in the total alumina, including that from the coke, and see what percentage of total slag it constitutes. If we have no choice of ores we can, of course, make no substitution to correct excessive alumina, but it is desirable to know in advance its approximate amount, because if it lies in the range which gives high viscosity and increased free running temperature, as pointed out in the article on slags, we must expect that this will have a corresponding effect on the burden which the furnace can carry.

In one such case pure silica and lime were added to the charge to dilute the alumina, but it is doubtful if this ever pays on account of the great increase in slag volume to secure any material dilution.

Where several ores are available with varying contents of silica and alumina, proportions of each can usually be chosen which will give the most desirable slag, or at least which will give a slag lying outside the comparative danger zone of high viscosity.

In calculating slags practically it is very necessary to remember that the sulphur must pass out of the furnace in the form of calcium sulphide, and if these calculations were as delicate as some would have us believe it would be necessary to add lime to supply the calcium for this purpose. But as a matter of fact the calcium sulphide in coke slags in ordinary practice does not vary very greatly except with very lean ores when its amount is smaller. In ordinary practice the sulphur carried by the slag varies from about 1.25 to 1.75 sulphur, and the calcium sulphide accordingly from about 2.75 to about 3.75 per cent.

A condition often arises which complicates slag calculations to some extent. That is that an ore may contain lime or magnesia or both. In this event we have two sources of base, one from the ore, one from the stone charged as flux. Obviously the lime required to be supplied by the flux must be reduced by the amount contained in the ore, but it is by no means a simple subtraction from the quantity of the flux because the lime as reported in the ore is pure lime and has an efficiency of 100 per cent, whereas the limestone is an impure carbonate of lime with an efficiency of generally less than 50 per cent.

Probably the easiest way to take care of this is, after obtaining the total weights of silica and of lime and magnesia in the ore charge, to deduct from the silica the amount which will be fluxed by the lime present at the desired ratio of lime to silica, and then determine limestone needed to flux the balance as before described.

In order to illustrate these principles let us run through one or two illustrations. Let us assume a coke of the following analysis:

	Per Cent
SiO ₂	5.00
Al ₂ O ₃	3.00
FeO ₂	1.40
(Fe =	1.0)
Volatile	1.75
Sulphur	0.85
Fixed carbon	\$\infty\$.00
Phosphorus	0.027
Moisture	2.00
	100.027

The limestone we will take as before:

CaO + MgO	52
SiO ₂	2
Al ₂ O ₃ + Fe ₂ O ₃	2
CO ₂	44
	100

Note.—Pure calcite contains 56 per cent CaO, but pure magnesite only 47.6 on account of the smaller atomic weight of Mg. True dolomite, CaO, MgO, 2CO_2 , contains 52 per cent.

The analysis we have taken represents a somewhat magnesian stone, but not a dolomite. If it were a calcite the CaO would be $(100 - 2 - 2) \times 56/100 = 53.8$, but if it were a dolomite the CaO + MgO would be $(100 - 2 - 2) \times 52/100 = 49.9$. This is a point always worthy of attention. Let us now suppose that we have available an ore which we will call A which analyzes in the natural (moist) state.

Fe.....	49.85
Phosphorus.....	0.072
SiO ₂	6.29
Al ₂ O ₃	3.52
CaO and MgO.....	

Let us assume first that we are to make basic iron and that the burden of ore will be 2.2 times the coke.

Let us assume that the furnace is a small one, and the charge of coke 9000 lb., which will never vary, so we can calculate the stone for the coke at once and be done with it.

The coke will contain 450 lb. SiO₂, 270 lb. Al₂O₃, and also 90 lb. of Fe which will go into the iron.

We will assume that the best ratio of lime to silica is 1.5, then the efficiency of the stone being 49 per cent, each unit of silica will require $1.5 \div 49 = 3.06$ units of stone, and the 450 lb. of silica in the coke ash will require 1375 lb. stone.

The ore burden on the basis assumed, 2.2:1, will be 19,800 lb., which will contain 9875 lb. of iron, 1245 lb. SiO₂, 696 lb. Al₂O₃.

The loss of Fe is about 3 per cent, but the carbon, silicon, manganese, etc., make up more than 5 per cent of the pig iron produced, so the yield of iron is about $97 \div 95 = 102$ per cent of the Fe.

The iron of the coke ash, 90 lb., added to that in the ore makes 9965 lb. and 102 per cent of this is 10,160 lb. Assume the silicon in the iron to be 0.75 per cent of 76 lb., then the SiO₂ to yield this becomes $76 \times 60/28 = 163$ lb., which obviously does not require to be fluxed, so we deduct it from that in the ore 1245, which leaves 1082 lb. to be fluxed.

This requires, as above, $1082 \times 3.06 = 3320$ lb. of stone which, added to that for the coke as above (1375 lb.), gives a total stone charge of 4695 lb.

Now let us see what sort of a slag we shall have. Let us for present purposes ignore the impurities in the stone and the sulphur in the coke, assuming the stone to contain only 49 per cent of CaO + MgO. We shall have:

	From coke	450		Lbs.	Per Cent
SiO ₂	From ore less that required for iron	1082	Total...	1532	31.9
Al ₂ O ₃	From coke	270			
	From ore	696	Total...	966	20.1
CaO + MgO	4695 $\times$ 0.49.....			2300	48.00
				4798	100.0

It will be seen that this slag contains a highly objectionable amount of alumina, which would make a tough, stringy slag, causing the furnace to work very "stiff," and probably not to settle regularly, while the superheating effect would tend to put silicon into the iron, the very thing we are trying not to do; in other words, we should consider this an undesirable ore for making any iron except high silicon, and would reject it for all other purposes except as a portion of a mixture on account of the high ratio of alumina to silica. The same ore applied to making foundry iron, of say, 2.5 per cent Si, would work out about as follows:

Assume the burden ratio in this case to be 2.0 instead of 2.2 on account of the greater coke requirements of foundry iron, and assume the lime-silica ratio to be

1.3 instead of 1.5, because with the higher heat in the hearth less lime will suffice for desulphurization. The ore will contain: Fe. 8970 lb.; SiO₂, 1132 lb.; Al₂O₃, 634.

The yield in this case will be on account of the higher Si of the iron about 103½ per cent.

The total Fe is $8970 + 90 = 9060$ lb. and the pig iron is 9400 lb. The Si is to be 2½ per cent of this or 235 lb., and the corresponding SiO₂ is 503 lb.

Deducting this from the total SiO₂ in the ore (1132 lb.), we have left to be fluxed 629 lb., which requires at the new ratio $629 \times 1.3 \div 0.49 = 1675$ lb. of stone. This added to the stone for the coke which now becomes $(450 \times 1.3 \div 49 \text{ lb.} = 1200 \text{ lb.})$ gives the total stone, 2875 lb.

The slag on the same basis as before now becomes:

SiO ₂	From coke	450	Lbs.	Per Cent
	From ore less that required for iron	629	Total....	1079
Al ₂ O ₃	From coke	270		31.8
	From ore	634	Total....	904
CaO + Mg	2875 X 0.49.....	1410		26.6
			3393	41.6
				100.0

I have never run a furnace on such a slag, and the information available concerning such slags is very scanty. Most furnace men would object very decidedly to running on such a slag, and probably with good reason. One set of furnaces of which I had knowledge ran very unsatisfactorily even on foundry iron, on slags, ranging from around 23 per cent to 27 per cent, but I have no knowledge of the lime-silica ratio they used; if the management was attempting to maintain a constant ratio of lime plus magnesia to silica plus alumina, as described in the paper before quoted, the cause of the trouble was not really the alumina but the lime.

The very general preference is always to keep the alumina under 18 per cent, and for steel-making irons not above 12 per cent to 14 per cent. It must be recognized that furnaces are being successfully run on slags of 24 to 28 per cent Al₂O₃, but it is done not because the slag is desirable metallurgically, but because the cost of the ore which gives such slags is low enough to compensate commercially for the disadvantages of somewhat smaller production and somewhat greater coke consumption than would result from ores lower in alumina.

Having purposely chosen in the first case an ore which would give an undesirable slag, let us now take a more normal one, which we will call B, which analyzes:

Fe.....	49.59
Phosphorus.....	0.050
SiO ₂	8.70
Al ₂ O ₃	1.91
CaO + MgO.....	

First let us take the case of basic iron and assume a burden of 2.2 or 19,800 lb. as before, then the coke charge being the same as before, we have $19800 \times 49.59 = 9840$ lb. Fe; adding 90 lb. from the coke we have 9930 lb. A yield of 102 per cent gives 10,100 lb. pig iron. The silicon in this at 0.75 per cent is 76 lb. and the corresponding SiO₂ is 163 lb.

The silica of the ore is $19,800 \times 8.70 = 1720$ lb.; deducting 163 lb., the silica to be fluxed is 1557 lb. The limestone for this at 1.5 to 1 and 49 per cent efficiency is 4770 lb., to which is added 1375 for the coke, making 6145 lb. stone. Then the slag formed is as follows:

SiO ₂	From coke	450		Lbs.	Per Cent
	From ore less required for iron	1557	Total	2007	35.4
Al ₂ O ₃	From coke	270			
	From ore	378	Total	648	11.4
CaO + MgO 6145 × 49				3010	53.2
				5665	

This is an excellent slag on which to make basic iron, and yet there is a certain feature of this case which compares unfavorably with the former.

The slag volume is one-sixth larger than in the former case, which means, other things being equal, a larger fuel consumption, but the free-running temperature of the low-alumina slag is enough lower to offset the greater slag volume twice over for *basic iron*. When foundry iron is to be made the higher alumina is probably an advantage as the lower slag volume certainly is.

These two ores, A and B, each contain almost exactly the same $\text{SiO}_2 + \text{Al}_2\text{O}_3$, 9.81 for the former as against 10.61 for the latter, but still there is a proportionally much greater volume of slag in the latter case; this serves to bring out an important point: Of two ores containing the same sum of $\text{SiO}_2 + \text{Al}_2\text{O}_3$, the ore which contains the most silica will always produce the greatest slag volume, for the silica requires to be fluxed with considerably more than its own weight of *lime* (not stone), while on the system recommended here no flux is added for the alumina. Let us now see how ore B works out for foundry purposes.

Assume the burden 2.0 or 18,000 lb., the Si in the iron as $2\frac{1}{2}$ per cent and the yield $103\frac{1}{2}$ per cent as before.

The total Fe is $8930 + 90 = 9020$. The iron is 9350 lb., the Si is $2\frac{1}{2}$ per cent of this, or 234 lb., and the corresponding SiO_2 502 lb. The SiO_2 of the ore is $18,000 \times 0.087 = 1565$; deducting 502 leaves 1063 lb. to be fluxed, requiring with a lime-silica ratio of 1.3 and the same stone as before, 2820 lb. stone. The slag in this case becomes:

	From coke	450	Lbs.	Per Cent
SiO_2	From ore less Required for iron	263	Total 1513	37.0
Al_2O_3	From coke	1070		
	From ore	344	Total 614	14.9
$\text{CaO} + \text{Mg}$	$(2820 + 1200) \times 0.49$	1970	Total 1970	48.1
		4097		100.00

This would be an excellent slag for foundry iron, though the alumina might well be raised a little, which, of course, could readily be done by using a certain proportion of A.

Most burdens are made up of several components, and in that case while the principle is the same we have more items to handle.

To show these more clearly, the results of a burden of one-third of ore A and two-thirds of ore B are shown in Table I, whose arrangement brings the separate components from whatever source into one column, so that the total amount of each to be disposed of may easily be found by addition.

This shows the phosphorus and sulphur as well as the slag-forming components. The charge contains

about 15 lb. of phosphorus, all of which passes into the 10,020 lb. of iron, making the percentage in the latter 0.15. The extreme limit for Bessemer rail steel is 0.1 in the steel, so the iron is limited to about 0.09 per cent. Iron with phosphorus 0.15 per cent would be classified as "malleable" by its phosphorus content, although much basic iron now made is as low as this.

These figures are not strictly correct, because while we have included all the impurities in the limestone which are present in the slag, of course, we have not made allowance for the manganese and traces of iron in the slag. Most of the sulphur in the charge must be carried off in the slag as CaS . Let us see how much lime is required for this. Suppose the iron to contain 0.03 S, then this will take care of 3 lb. of the 86 lb., and let us suppose that 15 per cent are volatilized, disposing of 13 lb. more, and leaving 70 lb. to be fluxed.

The Ca required for this is $70 \times 40/32 = 87.5$ lb., and the CaO corresponding is $87.5 \times 56/40 = 122.5$ lb.

This is 4 per cent of the total lime charged, and so reduces our lime-silica ratio by 4 per cent, or to 1.46 to 1.

This is within the limits of accuracy of our knowledge of the best ratio and is a small matter. If an exact ratio be desired the stone required for the sulphur can be figured once for all and added to the stone for the coke ash, but a slight change in the heat of the furnace, throwing more or less silicon into the iron, will make more difference in the actual basicity of the slag than all the sulphur does. For instance, a change of 0.25 per cent in the silicon in the iron makes a change of 25 lb. of Si and 54 lb. of SiO_2 , which would call for a change of 81 lb. of lime, but such changes are of daily occurrence, almost from cast to cast, and yet no furnaceman thinks of correcting his limestone burden to suit.

These simple examples illustrate the principles of figuring burdens of which so marvelous a mystery has often been made by those who wished to emphasize the importance of their own knowledge.

In general several ores or iron-bearing materials are used, but the principle of figuring the burden is the same for a dozen as for one.

These chemical considerations are only one of the elements in making up a burden. The physical condition of the ore, whether "lump," "fine," or "soft" (plastic), whether hematite or magnetite, whether excessively fine or only like coarse sand, and above all price, these are all questions which must be considered with the same care as the chemical composition of the ores. As a general thing it is a problem of fitting the physical properties of the ores available together in such a way as to give the charge the most desirable physical character for the least cost, then adjusting the proportions of the different components so that the ratio of silica and alumina will be within certain wide limits, and finally calculating the amount of stone required to give the ratio of CaO to SiO_2 needed for the kind of iron to be made. It is obvious from the statement of the problem that there is need for some cutting and trying of different combinations, a little simple arithmetic, and much common sense and judgment.

Of course, if Bessemer or special low-phosphorus iron is to be made, the increased selling price warrants a larger expenditure for ore, and in that case the necessity for keeping the phosphorus below the desired limit is paramount, and other considerations are subordinated to that.

In that case the phosphorus contents of the coke and the stone must be carefully watched, since ores bring a premium in proportion to the smallness of their phosphorus content, and the higher the coke and stone in

TABLE I

Material	COMPONENT									
	Fe		SiO_2		Al_2O_3		$\text{CaO} + \text{MgO}$		P	
	C_c	Lbs.	C_c	Lbs.	C_c	Lbs.	C_c	Lbs.	C_c	Lbs.
Coke	9,000	1 00	90	5 00	450	3 00	270	..	027	2 3
Ore A	6,600	49 55	3290	6 29	115	3 52	233	..	072	4 8
Ore B	13,200	49 59	6740	8 7	1174	1 91	252	..	050	6 6
Stone	5,740		2 00	115	115	52	2983			
		10020		2154		870	2983		15 1	86 1
				165						
			net	SiO_2	1989					

Iron produced basic $1.02 \times 10,020 = 10,220$.
 Si in iron at 0.75 per cent = 76.8; SiO_2 for this Si = $76.8 \times 60/28 = 165$ lbs.
 Total SiO_2 2039; deduct 165; balance 1874 SiO_2 to be fluxed.
 Stone to flux this at 49 per cent efficiency of stone and 1.5 $\text{CaO} + \text{MgO}$ per unit of $\text{SiO}_2 = 3.06$ units of stone per unit of SiO_2 .
 Correct slag volume
 SiO_2 2154 - 165 = Lbs. 1989
 Al_2O_3 870
 $\text{CaO} + \text{MgO}$ 2983
 Sulphur with allowance for volatilization, etc. 70
 5912 100 0

this element the more expensive the ore which must be used to keep the total within the desired limit.

Let us now hastily run through a case in which one of the ores is more than self-fluxing; that is, where the major impurity to be slagged is lime instead of silica. Let us assume a coke charge of 12,000 lb. of the following analysis:

SiO ₂	7 per cent
Al ₂ O ₃	2 per cent
Fe	1 per cent
S	1 per cent

We have available ore C containing:

Fe	33.00
CaO	17.00
SiO ₂	5.0
Al ₂ O ₃	2.0
CO ₂ with CaO	13.5

and ore D containing

Fe	47.0
CaO	16.0
SiO ₂	4.0
Combined H ₂ O	10.0

The burden will consist of three-fourths C and one-fourth D with an average Fe content of 36½ per cent.

The fuel we know will be about 2750 lb. per ton of 2240 lb. Then 12,000 lb. coke will produce 9800 lb. of iron nearly, and assuming foundry iron with a yield of 102 per cent, this will correspond to 9500 lb. of Fe, and at 36½ ore percentage this will give an ore burden of 26,000 lb., 19,500 of C and 6500 of D.

The silica in the coke is 840 lb. The lime-silica ratio being 1.3, the silica of ore C will use $1.3 \times 8 = 10.4$ per cent of its lime, leaving $(17 - 10.4) = 6.6$ per cent free for other purposes, or 1250 lb. of lime.

The silica of ore D is 1040; this added to that from the coke, 840, makes 1880 lb.

Assuming 2½ per cent Si in the iron, 244 lb. of silicon per charge is required, or 525 lb. of silica. Deducting this from the unfluxed silica above, 1880 lb., we have left 1355 lb., which requires 1760 lb. of lime. Deducting from this the 1250 lb. of free lime from ore C we have left 510 lb. of lime to be supplied by limestone. At 48 per cent efficiency this will require 1060 lb. of stone.

Neglecting the impurities in the stone and the sulphur in the coke we obtain the following slag:

		840	Lbs.	Per Cent
SiO ₂	From coke	1560	3440	42.0
	From C	1040		
	From D	240		
Al ₂ O ₃	From coke	390	890	10.9
	From C	260		
	From D	3320		
CaO	From stone	510	3830	47.1
			8160	100.0

These conditions are similar to those in the Birmingham district, but the ores there contain more silica and alumina than in the case taken, so that the slag volume there is larger and the alumina somewhat higher than in the above illustration. But the example shows clearly the method of calculating a burden for a calcareous ore. Of course, in such a case by lowering the proportion of D the change may be made exactly self-fluxing so as not to require the use of any lime at all. This has often been done in that district. Here we have a good illustration of what slag calculations *cannot* do; D represents a brown ore and C a hematite; it is found in practice that an admixture of brown ore lowers fuel consumption to a very material extent, and it is always used when available, but there is nothing whatever in the slag calculation to show this.

From the above examples it will be seen that the calculation of a furnace burden is by no means the complicated operation that some pretend to believe. It is no more than an old-fashioned sum in addition, sub-

traction and multiplication. We have only to remember the simple rule that everything which goes into the furnace must come out, and it must come out in one of four ways: as gas, as flue dust, as an ingredient of the iron, or as slag.

The foregoing articles have shown clearly enough those elements of the charge which come out as gas, the composition of the iron tells us approximately what will come out with the metal, the balance must appear in the slag, and that balance must be so proportioned as to make a free-running slag with a sufficiently high ratio of lime to silica to take care of the sulphur and yet permit the degree of siliconization desired.

In all the above it will be noted that little has been said as to the ratio of the ore burden to the fuel. We may as well confess now that this depends upon judgment much more than upon calculation, and the burden must in general be adjusted to what the furnace is willing to carry rather than to the preconceived ideas of anyone as to what it should carry. However, certain approximations are desirable, and in the light of the calculations of the article on thermal principles are possible.

If the conditions are normal, that is, if the slag contains only the ordinary ingredients in proportions within the ordinary range of practice, roughly speaking, silica, alumina, lime, and magnesia, if the alumina be below 17 per cent and the sulphur not much in excess of 1½ per cent, we can assume that we shall have a critical temperature of 2750 deg. If the conditions are different from these, if there are other elements to be fluxed, if the sulphur is excessive, or, on other hand, is much below normal, it is not possible to say quantitatively in advance what the effect on the free-running temperature of the slag will be, and we are, therefore, left in ignorance of the most important datum of the whole subject, the critical temperature of the furnace, and can, therefore, make no trustworthy calculations.

Assuming, however, that the critical temperature is normal we can say that the fuel consumption with a slag volume of half a ton per ton of iron will vary from about 1700 lb. in the best practice to 2100 or 2200 lb. in accordance with the fineness of the ore, the temperature and dryness of the blast, and, above all, with the goodness or badness of the filling. Each additional 100 lb. of slag per ton of iron will require about 35 lb. of coke up to 3000 or 3500 lb., and probably beyond that point, but that is about the limit of slag that it is commercially possible to melt in present practice, though undoubtedly with the exhaustion of our richer ores this limit will rise by slow degrees from year to year.

From these figures of fuel consumption we may easily work back through the percentage of iron in the ore and the percentage of Fe in the pig iron, to the quantity of ore which will constitute the burden which the coke may be expected to carry in the given case.

Any such calculation, however, is an estimate and nothing more. It may be used to obtain an approximate fuel cost under untried conditions or to check up an actual fuel consumption to see if it is out of the way, but in the day-to-day burdening of the furnace the only knowledge of any real value as to the burden the furnace can carry is supplied by the performance of the furnace itself after all the conditions have been made right.

The largest plant in the world for the synthesis of mustard oil is that of the Musterole Co., Cleveland, Ohio. The process was developed by Dr. D. Julian Block of the Block Laboratories, Chicago, and the equipment was furnished by the Elyria Enamelled Products Co., Elyria, Ohio.

Cost-Accounting in the Construction and Operation of a Copper Smelter—I

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Introduction

There are few responsible officials to-day, who will not grant the premise that costs should be kept on construction work. However, the question "What kind of cost accounts shall be kept?" is answered in a different way by each; the views range from one extreme to the other by insensible gradations. As an instance we will assume that a company is organized by up-to-date business men, who have appointed an eminent accountant as auditor, and a successful builder as engineer in charge of construction. The auditor reasons along the line that while the construction of the new plant will furnish the machine whose operation will provide the future dividends, the value of this property—consisting as it does of a multitude of items of land, building and equipment—represents only a small portion of the corporation's capital stock. This capital includes so many intangible values, such as patent processes, easements, good will, ore and selling agreements, etc., that its amount will be limited only by the amount of dividends which will probably be earned by the prospective works. The cost of construction, therefore, assumes a position of minor importance in his mind; the books must be accurately kept so that the disbursements may be properly accounted for, the total will be utilized as an item to be placed in a column headed "Assets," and only a minor amount of segregation will be necessary upon which to base insurance and depreciation.

"Accounts" as such, mean little to the engineer. The imposing total is footed up possibly some months after he has hurried on to other fields of endeavor, and then is jealously guarded from inquiring eyes in the distant general office. He is interested in "costs" rather than these "accounts"; in the past he has determined the labor and material cost on each of his jobs for comparative purposes. He has found that a proper study of the costs enables him to handle more men with fewer bosses and with greater efficiency; to check waste of material and labor; to prevent pay-roll padding, and correct improper design and distribution of his outfit. They give him a sure, infallible and immediate proof as to whether a job is extravagant or a foreman inefficient—sufficiently prompt to nip in the bud incipient wasteful conditions.

A great distance lies between the requirements of these two officials. The accountant will be satisfied if the accounts show that the foundations for a battery of reverberatories cost \$8,365.37. The engineer, however, expects his costs to show him that during the past month A's concreting gang mixed and placed concrete in the reverberatory foundations at the rate of three hours labor per cubic yard. Now if B's gang working this week under similar conditions in the blast-furnace plant costs four hours per cubic yard, Foreman B's work next week will be a good subject for close observation. Herein lies the essential differences between accounting and cost-keeping: Accounting has been developed by clerks, and utilizes dollars and cents in dealing primarily with minutely accurate debits and credits; cost-keeping has been developed by engineers and utilizes various standards of comparison in dealing with unit costs. These unit costs can be expressed in hours labor, pounds, feet or bags of material, all of which as desired may be reduced approximately to dollars and cents by the use of *average* rates for labor and material merely

as an expedient, making it possible to add hours labor to bags cement.

The auditor, however, will hesitate before he acquiesces to the desires of the engineer. He has in mind certain so-called "cost systems" installed by accountants of his acquaintance, in which expensive records accumulate in vast quantities not susceptible of easy reference and soon fall into hopeless confusion. Such a system will develop miles and miles of figures with perhaps not a single unit cost; the whole thing becoming an interesting and more or less valuable historical document, but of slight contemporary utility. Accountants seldom realize the essential differences between "costs" and "accounts" as sketched above; namely, that "costs" relate to the *items* making up the cost of an operation, and "accounting" starts in where cost-keeping ends. On the other hand the engineer should recognize the fact that he will not need a minute segregation worked up of every job every week, although the system should have the latent possibility of segregating any item upon demand. Erecting steel in the converter building will cost in the neighborhood of \$15.00 a ton for several weeks in succession, when suddenly it will jump to \$19.50 for no apparent reason. A close analysis and comparison of the work during the high-cost with the preceding low-cost week will invariably point out the root of the trouble which can then be closely watched and promptly remedied.

Essentials of a Cost System

A successful cost system possesses several essentials. It should be simple, economical, concisely detailed, convenient, and carefully correlated.

The requirement of simplicity can be furthered by a reduction in the number of forms used, these forms to be principally cards of a few uniform standard sizes. Colored cardboard can be utilized to differentiate between cards pertaining to totally different departments.

The requirement of economy precludes any excessive duplication of work. A time-card or warehouse order, for instance, should be utilized for more than merely posting the time or material sheets; it should be available for the minutest scrutiny of the cost clerk.

The requirement that the separate cards contain concisely detailed information provides for the latent possibility of segregation of any job upon the request of an official as the desirability for it may arise. By far the large majority of accounts will not require this expense every week, but all accounts should contain the necessary data.

The costs should be convenient for use. Here very strenuous objections of certain members of the accounting department will have to be met and overcome. Bear in mind, however, that the duty of the costs is to *furnish information*, and they must be in constant use to promote present efficiency. Convenience also demands adequate and prompt sorting, filing and indexing.

Correlation requires close co-operation between engineering, construction and accounting departments. Daily notations of work done should be made by engineers and timekeepers in uniform loose-leaf notebooks. Quantity estimates should be made weekly of every phase of the work, the whole collected under the appropriate headings at weekly intervals, and a summary drawn up for the information of the chief engineer, showing the total labor, material and expense, the quantity of work done, and the unit costs for the current week, for last week, and for the total to date. Weekly reports to the management will be made by the engineer, drawing attention to the causes of unusually high or low costs, and accompanied by numerous pho-

tographs showing the progress of the work, the conditions and difficulties present. Graphic charts or tabulations may be revised weekly to visualize affairs to the management.

The system described in the following remarks is believed to be adequate and acceptable to both accounting and engineering departments. It will give the bookkeeper the accounts segregated according to his desires with remarkable accuracy, and on demand will yield minutely detailed unit costs of any account, suitable for the uses to which a cost can be put by the management, or the engineering department. The cost of the necessary routine beyond that of the ordinary method is exceedingly small. The system has been tried on a very large reconstruction—the most difficult construction and accounting problem—and has proved successful. It will require a close co-operation between the engineering, construction and accounting departments—something unhappily absent in many works to-day, but which can be obtained by insistence on the part of the manager.

COST KEEPING SYSTEM

We will proceed with a detailed discussion of the manner of obtaining the three general classes of charges which form the sum total of an account: labor, material and expense.

Charges for Labor

By "labor" we limit ourselves strictly to the workmen and straw bosses whose time is directly chargeable to a job. Other labor, more or less indirect, such as foremen, clerks, toolmen, watchmen, engineers, draftsmen and supervision should be charged to "expense" and redistributed in the most approved manner.

An applicant for work gives the employment clerk his name, address, age, nationality and next of kin; receives a copy of the rules governing workmen, and the Safety Department regulations; and is told to return on the following day. In the meantime, the clerk investigates the records, and if there is no apparent reason why the man should not be employed, such as previous discharge, physical defect or advanced age, he is asked to sign a card bearing the information taken the preceding day, stating that he has read the rules and intends to abide by them. This is given to him as a "rustling card" and is a permit to seek work on the company's premises at his own risk. On putting this new man to work, the foreman takes up and signs the rustling card, sending it to the timekeeper's office as

authority to give the new employee a number, brass check, and time-card, and to place his name on the time-sheets.

On subsequent mornings the workman passes through the gate, surrendering his brass check for a time-card bearing his number and stamped by a time-clock. He then goes to the tool house or rendezvous of his gang, and if he is needed, gives his time-card to his foreman and is put to work. After turning in his tools at the end of the day, his time-card, properly filled out, is returned to him, which he passes in at the gate, receiving his brass number in exchange. The card is then stamped a second time by the time-clock.

This time-card will contain on its face all the information necessary for the accounting department. It will appear somewhat as in Fig. 1.

On the reverse side, the timekeeper will enter on the card the information necessary for the cost department distributions, as in Fig. 2. From this card, P. R. No. 1276, John Johnson, will be credited eight hours labor, \$2.00 on the time sheets. The accounting department will enter a debit against

60
Account C — Labor 5½ hours \$1.37
1
51
Account C — Labor 2½ hours 0.63
2

when the card will be filed in the cost department, serially with all others of the same date.

Methods of Collecting Information

The method of collecting the information placed on the time cards is an essential part of the system. As early in the day as is convenient, the straw boss lists the card numbers of his gang in a memorandum book and delivers them to the timekeeper on his first round. The timekeeper checks the men against their cards, and enters in his loose-leaf note-book on the page headed by the appropriate account, the date, pay-roll numbers of the men working, and a clear and detailed description of what they are doing, the location of the work, machines or large tools in use, any unusual conditions of weather, delays or other circumstances surrounding the job. On returning to the office, the timekeeper, who should be a young man with previous engineering training, fills out the cards according to the information at hand, leaving the column headed "number of hours" blank until just before quitting time.

The timekeeper should be assigned only as much territory as he can cover four times a day; on each trip he makes notations as on the first, conferring with the foreman to ascertain the time of any change in occupation of the workmen. On the last trip in the afternoon he compares his distribution with that kept by the foreman in his memoranda, and receives from him an estimate of the material used and its source, such

JAN. 15, 1915 7:45 AM. ← Time-clock punch on entrance	
Pay Roll No. 1276	Written at gate
Name. John Johnson	
Occupation. Iron	
Time Worked. 8 hrs.	
Rate per Hour. 25¢	
Total Wages. \$2.00	
Overtime. hrs.	
Rate per Hour.	
Total Overtime.	
Signed Harry Jones, Foreman	Signed by General Foreman
Construction Dept.	Time-clock punch on leaving.
JAN. 15, 1915. 5:12 PM.	

Filled in by timekeeper

FIG. 1—TIME-CARD

DISTRIBUTION OF TIME.			
Acct.	Hours	Work Done	
C. 60	2	Earth X	Per. 73 C.
"	1	Loading in Dump Wagon	
"	3	Loose Rock X	Per. 74 C.
C. 51	2½	Loading Gravel Cuts at	
C. 2		Placing for Footer 10	
Total.	8	at 25¢	2.00 Timekeeper

FIG. 2—REVERSE OF TIME-CARD (FIG. 1)

Lumber stks is best carried near the carpenter shop, as is bar-iron at the blacksmith shop, shapes and plates at the boiler shop, and miscellaneous small electrical goods at the electricians' shop. The clerk of the shop should represent the warehouse in the care of this material; inventories and orders being obtained every week. The powder houses should be entered only by the

fire boss, reporting his daily consumption to the time-keeper, who will issue orders every week against the inventory.

Charges for General Expense

The third and final class of charges to the cost of a job is called "expense," and consists of a proper proportion of a large number of accounts carrying salaries, supplies and miscellaneous expenditures which are incapable of being charged *directly* to the various jobs involved, owing to their general nature. The list of such accounts is a long one, and hardly needs more than enumeration in this place; the keeping and re-distribution of the "expenses" lies largely in the province of the accountant. Such as the following are more or less self-explanatory; they contain within themselves various items of salaries, supplies and expenses. They need not appear in the costkeeper's statements, as they affect all jobs of a similar nature in the same proportion. Those enumerated below may therefore be lumped together as "miscellaneous expenses."

General Office.
Engineers' Office.
Legal Department.
Claim Department.
Safety Department.
Donations.
Insurance, Fire and Accident.
Fire Protection.
Hospital.
Taxes.
Rent.
Interest on Funds.
Lost Time.
Roads and Tracks for Construction.
General Yard.
Change House.
Tool Houses and Hand Tools.

Other "expense" accounts can be absorbed in other ways, and will be carefully noted by the cost clerk. These will be considered in detail, and may be called:

Warehouse.
Stable.
Shops.
Power House.
Construction Machinery.

"Warehouse expense" will consist of a proportion, possibly at varying rates, of the "miscellaneous expenses" listed above, together with certain special items pertaining to the warehouse alone, such as: salaries, expenses and commissions of purchasing agents, inspection expense, wages and office supplies for warehousemen and clerks, interest on inventory, depreciation of warehouse and equipment, maintenance of same, breakage and deterioration allowances, light, heat and power. The total of this multitude of items is best absorbed by adding a certain percentage to the cost plus freight on the various items in stock, giving them a selling price which will pay for the cost of operating the warehouse. This selling price is the equivalent of the cost of goods delivered instantly, and may possibly be higher than prices quoted on similar articles at local stores; this difference representing the value of the convenience of having what you want when you want it.

The probable amount of each item making up the warehouse expense should be carefully estimated and the total adjusted with the idea of operating the warehouse with a small profit. The grand total thus obtained should then be divided by the estimated annual sales, and this percentage added to the average price of each commodity, the resulting selling price being kept uniform for a fiscal year. At the end of this time any adjustments necessary may be made for the following year, and the current balance charged into profit and loss. This is in conformity with the evident desirability of keeping the cost of power, supplies and shop service at least as stable and uniform as the labor rate in order that comparisons of unit costs may be illustrative of

actual conditions obtaining on the job. If the expense accounts were entirely closed out monthly, extreme variations in loadings would result, and one could easily see the effect on the cost per cubic yard of concrete if the price of cement varied between 65c. and 95c. per sack, machine shop expense between 75 per cent and 295 per cent of pay roll, and teams between 60c. and 90c. per hour.

The same general considerations govern the formation and distribution of stable expense. This account, by the way, should carry wagons, carts, plows, scrapers, and miscellaneous small equipment for teams. A price per hour should be fixed for team service at about the average wage of a good hired outfit, and the time of each team (consisting of team, teamster and wagon) carried on time-cards exactly the same as those used for other labor throughout the plant. At the end of the year, with proper stable management, a small balance will remain to the credit of the stable account.

The two accounts just discussed may seem to be misnamed "expense," inasmuch as the warehouse expense is entirely absorbed on the cost sheets in the prices paid for materials; while stable expense appears under "labor" as "teams."

Each shop should have its individual "expense" account, figured separately for the individual shop, and to which is charged the correct proportion of the miscellaneous expenses. Mechanics' labor, and the material they fabricate, is charged out on regular time and warehouse order cards direct to the jobs upon which they are working. Exceptional charges follow the general rule, that material and labor incapable of accurate distribution shall be charged to the shop expense. Such charges are: small tools, blacksmith coal, welder supplies, tool repair man, craneman, foremen and clerks. This account will take, in addition, a share of the master mechanic's salary, depreciation and maintenance of building and equipment, light, heat and power, and defective material and labor.

The best method of redistribution of this shop expense is a much controverted question. Charging it out as a proportion of direct cost of labor plus material is good practice only for shops with low labor cost turning out a very uniform product. Distributing it as a proportion of labor cost, appears to be equitable only for work done by uniformly skilled mechanics at bench work, small machines, or piece work. Charged as a proportion of labor time is a procedure to be recommended only for work using the same class and size of equipment. A very accurate method of charging out this burden is given in Bunnell's "Cost Keeping for Manufacturing Plants," page 149 *e.s.* Scientific exactitude in the distribution of shop expense is as impracticable as the determination of the exact amount of some of the charges forming the total—for instance "depreciation" and "power." Hence, for ordinary repair shops, such as those commonly installed at metallurgical plants, it will be eminently satisfactory to load all work done in the shop with expense figured as a percentage of the direct labor cost. All work and erection done wholly outside of the shop by shop mechanics should be charged with supervision direct, but no shop burden. A better way to handle outside work, however, would be to organize gangs operating entirely apart from the shops, called "smelter mechanics."

Power-house expense covers the entire cost of operating the power houses: engineers, firemen, supervision, oils, fuel, ash-handling expense, miscellaneous supplies, proportion of "miscellaneous expense," depreciation and maintenance on buildings, machinery, all pipe and transmission lines, and operation of substations. (Note that maintenance and depreciation of motors or other

power equipment inside a shop is chargeable to that particular "shop expense.") The accountant may subdivide this heading into a number of accounts each referring to a separate item or class of equipment. In any case a very careful estimate is made of the average value of the different kinds of power generated: electric, air, hydraulic and steam, and this will be the fixed selling price of power to the different users for the fiscal year. The service should be metered as thoroughly as possible to eliminate errors in estimating the distribution of power, and each account should be charged with the amount of power which it actually uses. To aid in this work, the timekeepers will report to the power-house clerk a daily statement of the operations and meter-readings for any machinery using power.

A separate "expense" account will be opened, covering "construction machinery"—large tools such as steam shovels, locomotives, dump cars, tripod drills and channelers, concrete mixers, hoists, derricks, cableways, locomotive cranes, pile drivers, and any other items of machinery of such size, life and general utility as to warrant their cost being carried as assets. These tools should be rented to the various jobs as needed at an hourly rate sufficient to care for the maintenance and depreciation charges; the supplies and power necessary for their operation, however, being paid by the account where they are in use. A statement covering the detailed operations of such a machine should be filed daily by the timekeeper, who will also turn in a time-card for the machine, made up similarly to that previously indicated for a laborer. Such procedure is in line with our ideal that rates making up comparative costs should be as uniform as possible; not a violently fluctuating quantity due to charging out the cost of a general overhauling of a steam shovel, for example, during a month of low excavation.

Determining Unit Costs

Now that the methods of handling the various charges have been discussed at some length, let us see how they can be used by the cost-clerk. Suppose that for some reason the chief engineer has asked for particulars concerning the converter building excavation, week of Jan. 10 to 16, 1915. The cost-clerk will refer to the time-

60

keeper's notes of account C—. There he will find re-

1

corded the payroll numbers of the workmen engaged, as on Jan. 15; man No. 1276. Taking the bundle of time cards dated Jan. 15, he rapidly turns to 1276, and there has a detail of the work which that man performed. The notes will refer him to the proper warehouse orders for details of the material used, and on investigation he finds that order No. 12,836 covers $\frac{1}{2}$ pint cylinder oil for hammer drills working on C line piers. The notes also show that the hand hammer drills were working, referring him to the data for the correct charge for compressed air used. In this manner the cost-keeper collects all the labor, material and expense, segregating it into each classification for every pier. The civil engineer's quantity notes are included, wherefrom he derives the yardage of all quantities and computes the unit costs. The notes can be relied upon to give methods of doing the work, disposal of earth, difficulties, and all such essential information bearing upon comparison of costs. In case of machine operations, he will find the most of this information summarized on the daily report covering its performance.

The bulk of the cost-clerk's work will be making out the important warehouse orders and time cards for machinery, and representing the chief engineer in the

clerical department. Unit costs of a large number of items of work will be figured as a matter of routine, in order to call the chief engineer's attention to any abnormality when such are discovered. The foremen and straw bosses should be notified concerning their weekly costs, with comparisons to former periods or other gangs. These and other expedients should be resorted to in order to keep the organization well informed. The cost of the whole will be amply repaid in the increased efficiency of the organization.

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The Grading Industries

BY EDWARD S. WIARD

(Continued from Page 388.)

Revolving Screens

The principal value of the friction roller mount is that it permits the screen to be open from end to end. At one time I endeavored to design a revolving screen to rest on friction rollers for use in ore treatment, believing such a screen could be made much lighter than one provided with spiders and would permit a screen in need of repair being readily picked up by the proper grappling apparatus, one in perfect repair being substituted for it. But the lightest design which could be drawn up had a total weight about a third more than a screen of the same effective length supported by spiders and central shaft. The elements which made for greater weight were: the two tread rings, the gear ring and the increased length of the screen to support these members and the angle irons for connecting the tread rings to give the necessary rigidity to the apparatus. Such were the elements of greater weight for a dry screen. At the same time an attempt was made to design a wet screen of the same kind, and additional weight over the dry spiderless screen was obtained because of the necessity of providing grit guards and extra length of screen to support them. The guards encircled the screen at either end and consisted of multi-grooved rings to prevent grit from advancing along the screen and into the friction roller bearings.

Where screens are arranged in series the coarser screen should be placed first and successively finer ones below. This arrangement gives greater capacity, better screening effect and less wear on the screens than any other. In some designs the screens in a battery are arranged concentrically on the same shaft. While this arrangement results in economy of space it is very poor practice and should be permitted only where operations are transient in character, as for example for a temporary use by a contractor. The great practical disadvantage which results from the arrangement is the necessity of dismantling the whole screen for the repair of a single one.

Motion of a Single Particle in a Revolving Screen

Such theory of the motion of particles in a revolving screen or trommel as has appeared in print will be found set forth in treatises on ore dressing.¹ The theory is imperfectly or incompletely set forth in all these works, but space in these articles will be given only to touching upon the omissions in the works cited. In most revolving screen problems the trommels are revolved at speeds in which centrifugal force is of small moment. Thus in the majority of problems the standard practice is to revolve 36-in. screens twenty times a minute, 42-in. screens eighteen times a minute and 48-

¹English Works: Ore Dressing, Richards; Dressing of Minerals, Louis; Theory and Practice of Ore Dressing, Wiard.

in. screens seventeen times a minute as a maximum.

A single particle of material introduced into a trommel in rotation, starts from the lowest position of the screen at rest and rises with the motion of the screen on an arc at right angles to its long axis and partakes of the motion up to a point where the tangential component of its weight makes a line which coincides with the angle of friction, and then to a somewhat higher point due to the increased normal pressure caused by centrifugal force, which of course varies with the speed of rotation of the trommel. Beyond this second point the particle continues to rise by momentum, but it decreasingly partakes of the motion of the screen. During this period the particle follows the path of a parabola projected on a cylinder which is another parabola, but flatter. When the particle reaches the highest point in its upward travel and is at rest with respect to a fixed point, it falls along an ellipse whose major axis is that of an ellipse formed by the traces of a vertical plane passing through the screen and whose minor axis is the diameter of the screen. The particle does not, however, return to a position at the bottom of the screen but, as Louis has shown, to a point above this; that is the particle will fall through an arc which is double that through which it rises from the point where it ceases to partake entirely of the up motion of the screen. On the next cycle of up and down motion the particle will rise and partake of the motion of the screen entirely through an arc which is equal to the arc through which it will rise by momentum. These various arcs mentioned are all measured in planes at right angles to the long axis of the trommel.

Louis' mathematical discussion of the motion of a particle in a trommel very well explains the characteristic up and down swinging of the bank in a trommel and it also makes clear why the bank maintains a general position on the lower side of the trommel rather than at the bottom; but no attempt is made by him to measure the effect of centrifugal force. In the theory which is stated in Richard's Ore Dressing the particle is assumed to rise to a point where it has a sliding angle depending upon centrifugal force and the normal component due to weight. The particle is then assumed to slide down to the lowest point in the trommel in the elliptical plane which has been mentioned above, when the cycle is again repeated. According to this theory there is no explanation for the swinging up and down of the bank, and the particle should rise to a point where friction, centrifugal force and the weight are balanced when it should remain poised as long as the trommel is in motion.

Motion of a Mass in a Revolving Screen

So much for the theory of a single particle in a trommel. When a mass of ore is present the characteristic swinging of the bank diminishes in amplitude as the rate of feed increases, but the rotation of the bank tends to increase. Also, other things being equal, as the size of the material fed diminishes the amplitude of the swing increases and rotation diminishes. In order to understand what is meant by the term rotation the mind must be fixed on the particles of the bank collectively, remembering that each is endeavoring to pass through the cycle of motion which has been described. The lower lines of particles in contact with the screen endeavor to push the upper ones above the point where they would be carried if alone in the screen; and it is quite evident that the moment they reach a point which is in the sliding plane of the size and kind of material in the trommel, they will slide down the face of the bank and when they reach its lower edge they will again pass up to their former position unless in the meantime elim-

inated by passage through the screen apertures. This action causes a rotation of the bank which is greatest at the borders and diminishes inwardly toward its center. The upper bounding surface of the bank is a more or less unstable plane.

The possibility of the particle passing through the apertures is nil while the bank is rising and partaking of the motion of the screen, and increases to a maximum up to the point where the particles slide down the bank. So far as the grains in contact with the screen are concerned the best effect is obtained when the bank is falling and becomes a maximum when the bank comes to rest. The particles which slide down the face of the bank come momentarily in contact with unoccupied screen surface where they may be eliminated. The effect of the rotation of the bank is to bring the coarse particles to the periphery, and this action tends to bring undersize particles of nearly the size of the aperture more frequently in contact with the screening surface than grains smaller than these. As the load on the trommel increases the swinging of the bank decreases and the shaking down effect produced by the drop of the bank is not so sharp, and the small undersize grains in the center of the bank have less and less opportunity to reach the screening surface by interstitial action.

Slope and Length of Trommels

The slope of revolving screens ranges from a small fraction of an inch up to $1\frac{1}{2}$ in. to the foot and higher; the tendency in late years has been toward the higher figures. With the higher slope, while the progress through the screen is more rapid, the bank is thinned out and there are more chances for the grains of undersize to get through the screen. In the majority of problems with all kinds of screens the bulk of the undersize is removed at a very short distance below the point where the material enters the screening device; and where very great precision in the screening is not necessary, increased length beyond a certain amount adds very little to the total amount of undersize discharged. This will be quite evident on a little reflection. It has been shown that it is very difficult to get rid of the grains of very nearly the size of the apertures. When the bulk of the small and easily eliminable grains have passed through the apertures, which happens near the upper end, the volume discharged must continue to fall off very rapidly from point to point as the material being sized progresses toward the discharge.

Now with revolving screens the difficulty of eliminating the comparatively large grains of undersize is very much greater than with a flat screen because of the inclination of the apertures; that is to say, so far as particles falling vertically through the holes is concerned the width of apertures varies from zero when the holes are passing the horizontal central plane to their full size when the holes are passing the lowest position. Consequently the space where particles of widths near that of the aperture can fall through freely by gravity alone is very narrow. It is quite true, of course, that many particles of large size find their way through apertures by rebound in very much the same way that the ball in Japanese ping-pong finds its way into the depression in the surface of the table employed in this game; but it should be noticed that this effect is only obtained when the ball is coming to rest. Again, since the screening is done in a mass of some depth, some large grains will be forced through the apertures by the pressure of the mass above when such grains are at some heights above the lower center line of the screen.

Advantages of the Trommel

Considering the whole grading field, revolving screens are more commonly employed than any other single de-

vices. I will go briefly into the considerations which make them popular. The first point in their favor is their almost perfect balance. Second, their ability to do fairly good work even when heavily overloaded. Third, their freedom from blinding, due to the fact that there is no motion tending to jam a grain down in the aperture as there is with shaking screens; but the revolving screen ought not to be superior in this respect to gyratory or flat screens which advance the material without any motion tending to jam the particles in the apertures. Fourth, with flat screens of any width it is necessary, in order to secure the best effect, to distribute the feed evenly over the width of the screen, while with revolving screens it is necessary merely to discharge the feed into the upper end of the screen. Fifth, the rotation of the bank of material produces an active tumbling about of the particles on top of the bank, and when these grains reach the screen from time to time they are in different axial positions and this renders their elimination more easy if they are of irregular shape. This action is most marked with coarse dry non-adherent material. With fine material there is some adherence of the grains which is sufficient, when they are heaped up as they are in the trommel, to make the screening effect less than with a flat screen.

The great field of the trommel is for a range of material whose largest grain is $\frac{1}{2}$ -in. or larger. Screening wet, the deficiency of the trommel becomes marked as the size of the largest grain decreases. At a quarter-inch and smaller the bank rotates little or at all, although at every movement of the bank there are small slides of material at the lower edge. With fine damp material the bank slides back and forth practically as a single mass and screening takes place only at the area immediately in contact with the trommel. The shaking down or interstitial effect is small in a trommel as compared with a shaking screen, but with coarse dry material it is effective to some extent and helps rid the bank of undersized grains.

It has already been stated that the application of water to a flat screen is a failure, for it drains through, leaving a sticky non-progressive mass behind it. Within certain limits this is not true of the trommel. The water being applied in a sheet along the up-coming side, much of it falls without the trommel and does no good. The balance passes within the screen and flows down under the bank, where it is held by the particles as it would be by a sponge, keeps the grains from cohering, lubricates them in their passage through the apertures and carries undersize through by direct flowage. This effect cannot, of course, be obtained with a flat screen, for the water from a spray drains through as fast as applied. On the other hand, the balance of the bank is heaped up in a damp cohering mass, fatal to good screening. With any type of screen using some form of spray for washing, increasing amounts of water are necessary to keep the material in a loose condition, until a point of fineness is reached which requires that the material to be screened be practically suspended in water. With a less amount of water such material will cake on the screens or smear over the opening, so that no screening can take place.

Disadvantages of the Trommel

The principal disadvantage of the trommel or revolving screen is the time consumed in making screen changes and general repairs. For light screens, such as are used in Western ore mills, the most practical means of support is by central shaft and spiders. If these be provided with single drive, which is the approved method, there is no reason why the whole screen cannot be lifted from the boxes by the proper grappling

apparatus, and a new screen substituted. If the screens be arranged in series, a track and trolley can be installed, carrying the necessary tackle.

A disadvantage often cited against revolving screens, and one which is of no moment, is the fact that only a part of the screen is in use at any one time. But before the particles leave the screen they will have traveled over the whole surface many times. The whole essence of the problem may be stated thus: Which is the better mode of screening, given the cubical contents of the stream entering a screen as so much per minute or any convenient unit of time? Will it be better to send this over the screen one layer deep, requiring a high speed of so much advance per unit of time, or to reduce the speed of advance so that the material has a better opportunity to fall through the apertures? I believe there is no doubt that the first principle is better; but at the same time it should be observed that if the flat screen were reduced in speed so that the grains would pile up to the depth they do in the bank of the revolving screen, the efficiency would be far less for the same width of screen space occupied.

In the case of the revolving screen, as has already been demonstrated, the advance depends on the number of rotations of the screen and its diameter; but at the end of each cycle of path the material has advanced an amount equal to the end of a right-angle triangle whose acute angle is the angle of slope of the screen and whose other sides are the chords of the circular arc up which the material advances and the elliptical path through which it descends. So far as the material in direct contact with the trommel is concerned, there is of course no screening on the up movement until the angle of slide is reached. Above this point, since the motion of the screen is greater than that of the particles, there is a chance for grains to pass over apertures. On the down movement the number of apertures passed over is increased over the number which would be passed over if the screen were not revolving, by an amount equal to the number of apertures which would pass a grain if the latter were stationary. Consequently, if the whole number of apertures passed over is determined, it will be much greater than on a flat screen with an equal depth of bank and the same length as the revolving screen; for in the case of the former the rate of advance is also a measure of the number of apertures passed over, while with the latter the rate of advance of the bank as a whole is measured by the distance the particles fall forward at each swing of the bank; but the number of apertures passed over is very much greater than the number covered by the forward movement with flat screens.

Limitations of Revolving Screens

A revolving screen is bound to form a more or less deep bank, and as this proceeds toward the discharge point the elimination of undersize becomes progressively more difficult. That is, the finest of the grains are liberated first and much more largely than grains of greater size; then successively larger sizes are eliminated, but under the principles already enumerated the percentage of these grains eliminated becomes less as the grains approach the size of the aperture. At the lower end of the revolving screen unless it be overloaded the bank consists of grains larger than the aperture, and of course quite a range of grains which should have passed through the apertures. It is to be noted, however, that unless precise work is demanded, the appearance of the bank at the discharge point is satisfactory to the eye which only notes that there is an absence of fine material and that the oversize grains appear of the same general size.

For grading fine sizes, say below $\frac{1}{8}$ -in. diameter, the revolving screen is bound to do inferior work, as will any screen which attempts to handle too deep a mass. The revolving screen is consequently preeminently one for large capacity, coarse gradings and fairly good quality of work. If the revolving screen be loaded so as to cause the bank to occupy an arc of 90 deg., the effective screening width will be nearer to the projection of this arc, owing to the increasing angle at which the apertures are placed passing up to the 90-deg. position.

For a 48-in. trommel the projected width of the bank will be 2 ft. and the circumference of the screen 12.5 ft. With the same rate of feed a flat screen would require a width equal to 60 per cent of the circumference of the trommel or 7.5 ft. Consequently for commercial results two flat screens $3\frac{3}{4}$ ft. wide would be required to give the same results as one 48-in. trommel. Where the loading for a screen is so light as to make the width immaterial, the advantage is of course in favor of flat screens which will not occupy the floor space of the revolving screen. The revolving screen can increase its area of contact as the load increases, but other factors remaining the same, that is speed, surface, etc., the flat screen with increased loading will increase the depth of bank without increased screening surface.

Revolving Screens Employing Centrifugal Force

In addition to the ordinary forms of revolving screens with slight slope of the screening surface, there are vertical and horizontal types which run at a very much higher speed and cause the material fed to them to occupy the whole surface of the screen owing to centrifugal force. Where screens of this type are employed, special devices must be used to move the feed in a direction contrarywise to the motion of the screen; for, as must be evident, under high speeds the grains would cling to the screening surface and there would be no screening action whatever. Some of the devices employed are stationary vanes in contact, or nearly in contact, with the screen, which hold the material and cause the screen to slide over it. Other devices employ revolving vanes or brushes revolving in a contrarywise direction to that of the screen. If the material fed were to any degree abrasive, centrifugal revolving devices would cause great wear on the screen and the vane. Such devices are therefore limited to applications where the material fed is soft, such as flour-milling products; and in these cases the rubbing action is very helpful in unblinding the screen. The ordinary range of size of centrifugal reels used in flour milling is from 24 to 39 in. diameter and from 5 to 8 ft. in length. The 24-in. reel will run from 200 to 180 r.p.m. The reel shown in Fig. 1 runs at 100 to 130 r.p.m. and is made in diameters ranging from 24 to 30 in. The illustration shows a spiral brush revolving contrarywise to the motion of the screen.

Blinding of Screens and Methods of Prevention

Blinding is of two kinds: (1) agglutinative, as with flour mill products, which is relieved by brushing or

rubbing on yielding screens; and (2) of the sort where the particles are not deformed but are jammed in the apertures. Square apertures are worse than round in this respect. In flour bolting machinery, loose discs of various shapes are used, being allowed to slide around freely on the bolting cloth. Chains also are used for the same purpose. Fig. 2 illustrates an adaptation of this kind. For revolving screens, particularly those of polygonal shape which lend themselves to a ready adaptation, tappet devices are employed; but these are not very helpful and have the disadvantage of loosening bolts and other parts of the screen. For ores and rocks the occasional beating out of the revolving screen with a piece of belting mounted on a handle is probably about as efficacious a method of clearing the apertures as is practicable. At one of the Western ore mills relief from



FIG. 2—PREVENTION OF BLINDING BY CHAINS

excessive blinding of a fine screen was obtained by mounting the trommel on a sufficiently light shaft, so that this member and the screen, by suitable means, could be kept in a state of rapid vibration.

For flat screens, rope beaters with a number of tappets have been proposed, one end of the rope being secured to the discharge end of the screen and the other fixed to the frame of the actuating mechanism. When the rope with its attached tappets is drawn taut by the advance of the screen, the tappets give the under side a sharp blow. Endless-belt screens may possibly get relief from blinding to some extent by the wedged grains being forced out on passing over rollers. Roller systems also have been proposed for revolving screens. For medium soft materials these devices may give some relief, but where the wear on the screens is rapid they would interfere with patching.

Screen Materials

The materials used for making screens are (1) cast plates; (2) grizzly bars of various shapes, the standard sizes and weights being shown in Fig. 3; (3) brass and iron cloths; and (4) silk cloth. Cloth can now be bought with openings up to 4 in. in the clear and with wires as heavy as 1 in. in diameter. At the other extreme in brass cloth, 300 meshes to the linear inch can be obtained, the diameter of the wire being 0.0016 in. and the net linear opening 0.0017 in. For abrasive materials of coarse sizes, punched and cored-hole cast metals have advantages over cloth. They do not blind so

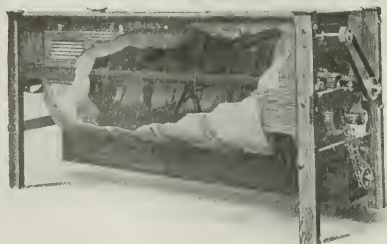


FIG. 1—SPIRAL BRUSH IN CENTRIFUGAL REEL

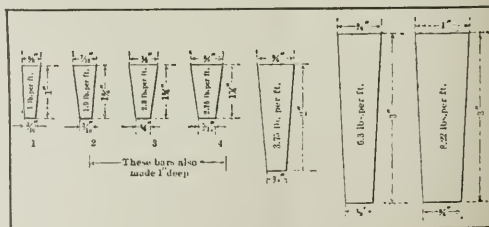


FIG. 3—GRIZZLY BARS

readily, their life is longer, and they are more securely patched. The principal disadvantage is the lower percentage of opening, and for average size openings, the greater cost than for steel cloth.

For round holes in punched metal the standard area of opening is about 33 per cent of the whole, which means that the width of space between holes is nearly equal to half the diameter of the opening. If the thickness of wire in metal cloth be considered equal to this much stock between the holes, which it is not, then the price of steel cloth for all apertures of the same width as the diameter of the round holes is increasingly less below $\frac{3}{8}$ in. Other things being equal, that is, neglecting other factors except wear that may affect the choice between perforated metal and steel cloth, the dividing line would be in the neighborhood of $\frac{1}{4}$ in. aperture; so that for equal wear the cloth would be cheaper below that mesh, and of course it would have a greater percentage of opening. Where there are corrosive forces at work, as in wet screening, the wear of the screen on this account may be much greater than abrasive wear. With very fine screens and wet screening, the combination of rust and blinding creates conditions which can be coped with only by a fine punch and hammer.

Sizes of bolting cloths and grit gauzes are shown in Table 1. In the weaving of these fabrics the warp threads are doubled and twisted about the woof thread, the whole being held in shape by treatment with a gelatinous or similar sizing material. Silk fiber is of great strength and smoothness. As compared with steel or brass, however, it is inferior in resistance to abrasion; but in the form of cloth or gauze it escapes much abrasive action by yielding, and in sizes below 30-mesh this cloth is cheaper than brass. In screening some dry materials, such as flour, the use of silk cloth is compulsory owing to the contamination which would be introduced by the corrosion of iron and steel. Silk cloth is damaged by moisture, and the grit gauzes go to pieces if they become wet.

Volumetric Grading

The McKesson-Rice screenless dry sizer has been so thoroughly described* that very little reference to the device need be made here. The range of the machine is from 4 in. or larger, if required, down to and somewhat below the limits of the finest screen. Its grading work

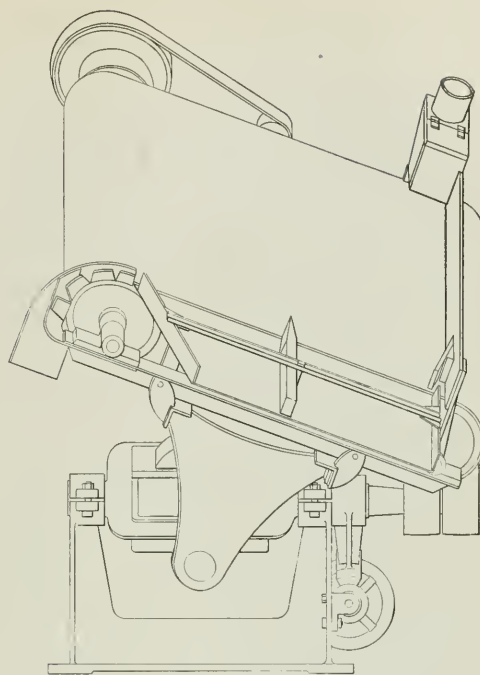


FIG. 4—BELT-TYPE SCREENLESS SIZER

on the finest dust is not very good. The machine can be arranged to deliver simultaneously any desired number of sizes. The particles delivered in any particular size are approximately of the same volume and the chief underlying principle of the device is rolling friction. The machine is made in two types, an inclined vibrating deck for coarse sizes and an endless inclined vibrating corrugated belt for the finer sizes. A late model of the second type is shown in Fig. 4. For capacities, description of action, quality of work, etc., reference should be made to the citations below.

TABLE 1

Silk Cloth and Gauze Screen

Cloth		Grit		Gauze		XXX Grit	
Number	Mesh	Number	Equals	Number	Equals	Number	Equals
0000	18	14		14		14	16
000	22	16	0000	16		16	18
00	28	18		18		18	20
0	38	20	000	20		20	22
1	48	22		22		22	24
2	54	24		24		24	26
3	58	26	00	26		26	28
4	62	28		28		28	30
5	66	30		30		30	34
6	74	32		32		32	36
7	82	34		34		34	38
8	86	36	0	36		36	40
9	96	38		38		38	42
10	108	40		40		40	44
11	116	42		42		42	46
12	124	44	1	44		44	48
13	128	46		46		46	50
14	140	48		48		48	52
15	150	50	2	50		50	54
16	156	52		52		52	56
17	164	54	3	54		54	58
18	168	56		56		56	60
19	172	58	4	58		58	62
20	176	60		60		60	64
21	182	62	5	62		62	66
22	186	64		64		64	68
23	192	66	6	66		66	70
24	196	68		68		68	72
25	200	70	7	70		70	
		72		72		72	

Note: Cloth and gauze 40 in. wide. Cloth in four weights: standard, X, XX and XXX. Mesh is exact count per linear inch; for XXX quality, one number coarser.

Tungsten in Boulder County

Mr. Warren F. Bleeker, president of the Tungsten Products Company of Boulder, Col., recently visited New York City and other Eastern points on business for his company. Mr. Bleeker was formerly general superintendent and research engineer for the Standard Chemical Company of Pittsburgh, Pa. Last fall he severed his connection with this company and associated himself with Mr. Horace B. Holmes, a well-known mining man of Boulder County, Col., and formed the Tungsten Products Company. This company treats Boulder County ferberite ores in its mill at Boulder by chemical processes designed by Mr. Bleeker. Tungsten concentrates, tungsten compounds, tungstic acid and metallic tungsten are being produced.

On his present trip Mr. Bleeker brought several thousand pounds of pure tungstic acid for the partial fulfillment of a special order requiring this grade of product. The company is planning to establish a permanent business in the milling and refining of tungsten and other rare metals, and the production of compounds of these metals.

*This journal, Oct., Nov. and Dec., 1911.

Review of Recent Progress in Electrolytic Iron*

BY OLIVER W. STOREY

Electrolytic iron, up to within the past few months, has been a laboratory rather than a commercial product, but recent developments show that it is another electrochemical achievement to take its place among the industries of this country. At least one of the large electrical concerns is turning out 1000 lb. (453 kg.) of electrolytically refined iron per week with a probable increase to several times this output in the near future. The method used is that developed by Burgess¹ and later modified by Watts.² The electrolyte consists of 150 grams of $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, 75 grams $\text{FeCl}_2 \cdot 4\text{H}_2\text{O}$, and 120 grams $(\text{NH}_4)_2\text{SO}_4$ per liter, with a specific gravity of 1.125 at 20 deg. C. Ammonium oxalate is used as an addition agent. The anodes consist of bars of basic open-hearth steel. The deposit reaches a thickness of $\frac{3}{8}$ to $\frac{1}{2}$ in. (10 to 13 mm.) before it is necessary to remove the cathode.

While the electrolytic refining of iron is an infant industry at the present time it is well to remember that electrolytic zinc refining was at the same stage of development a year ago. Two years ago it was thought doubtful whether the problem could be solved except in the distant future. Now we read in the technical press of the erection of electrolytic zinc refineries whose cost will amount to several millions of dollars. With this example before us who can predict what the next few years will accomplish in the electro-deposition of iron?

Electrolytic iron is known to have been produced on a laboratory scale seventy years ago. As long ago as 1860 it was used for the plating of copper engravings for the printing of bank notes at the Imperial Mint at Petrograd, Russia. Until recently the only use to which electrolytic iron had been put was in the so-called "steel facing" of dies and electrolytes. Its hardness, which makes it suitable for such purposes, is due to hydrogen, either occluded or combined.

The commercial production of electrolytic iron as a source of pure iron received a decided impetus in 1904 when Burgess and Hambuechen presented their paper on "Electrolytic Iron" before this Society. They showed that it was possible to refine iron by methods similar to those used for the refining of copper and obtain deposits up to 1 in. in thickness. The electrolyte consisted of a neutral ferrous sulphate solution containing some ammonium sulphate, while the anodes consisted of slabs of wrought or other soft iron. The current efficiency of deposition was near 100 per cent and the resulting iron was of a high degree of purity, containing less than 0.10 per cent and often under 0.03 per cent of impurities. Over three tons of iron was refined and used for the production of over 1000 "pure iron" alloys which were tested for their various properties.

After several years' experience upon a semi-commercial scale at the University of Wisconsin, Burgess³ gives the following figures on the cost of commercial refining of mild steel, the product being an iron of a high degree of purity. He estimates the power cost per ton at \$10, with power at a cent per kilowatt hour, one kilowatt hour producing 2 lb. (907 g.) of iron. The cost for labor, solution maintenance and fixed charges is estimated as equal to the power charge or \$10. The anode

material is assumed to be a mild steel costing \$35. This would make the total cost about \$55 per ton of refined iron. With power at $\frac{1}{2}$ cent per kilowatt hour this cost would be reduced to \$50.

In 1908 Cowper-Coles⁴ described a method of making finished iron sheets and tubes by electrolytic methods from pig iron or from iron ore, using insoluble anodes when ore was used. The electrolyte was a 20 per cent solution of sulpho-cresylic acid saturated with iron. The method differs from the Burgess process in that pig iron and iron ore are refined, and in a different choice of electrolyte. The process has not been used commercially though it is stated that works are being erected for the manufacture of electrolytic iron by this method.⁵

A detailed description of the Cowper-Coles process is given by Palmaer and Brinell.⁶ They state that the electrolyte is a concentrated solution of ferrous chloride with additional organic compounds, such as the cresol-sulphonic acids, and enough iron oxide to make a sort of a gruel. The additional iron oxide is used for reducing the acidity and polishing the iron which is deposited as a sheet on a rapidly revolving cathode at a temperature near the boiling point of water. The current density used is about 63 amp. per square foot (7 amp. per square decimeter). The resulting product is brittle due to the presence of several tenths of 1 per cent of hydrogen. It also contains about 0.50 per cent of impurities, exclusive of hydrogen, while the pig iron used for anodes contains about 7 per cent. The chlorine content of the deposited iron is high, probably being occluded electrolyte. This is a serious defect as it impairs the mechanical properties and promotes rusting. The figures given by Palmaer and Brinell show that the cost of the electrolytic iron would be from $2\frac{1}{2}$ to 3 cents per pound (453 g.), depending upon the cost of power, though the inventor claims that the cost is below 2 cents.

In 1911 Fischer took out patents⁷ for the manufacture of ductile electrolytic iron in which he claims that ductile iron may be deposited from a hot solution of ferrous chloride if hygroscopic salts, such as the chlorides of calcium, magnesium, or aluminium, are added to the electrolyte. He claims that the ductility of the product increases with the electrolyzing temperatures and that perfectly ductile iron is obtained at temperatures varying between 100 deg. and 120 deg. C. The preferred solution consists of a highly concentrated mixture of ferrous and calcium chlorides, 450 parts of ferrous chloride, and 500 parts of calcium chloride being dissolved in 700 parts of water. Under these conditions a current density of 180 amp. per square foot (20 amp. per square decimeter) may be used.

Fischer's method for the production of ductile electrolytic iron is used by the Langbein-Pfanhauser-Werke of Germany for the commercial production of sheets and other articles. Duisberg⁸ states that by this method the iron is deposited free of hydrogen and that its hardness sinks below that of silver and gold, and is not much greater than aluminium.

Ramage⁹ took out a patent in 1911 in which he makes electrolytic iron from iron ore. The ferric ore is dissolved in sulphuric acid and reduced to the ferrous state by sulphur dioxide. The anode compartment of the electrolytic cell is separated from the cathode compartment by a diaphragm. The portion of the electrolyte in the anode compartment is kept saturated with the sul-

*A paper read at the Washington meeting of the American Electrochemical Society on April 29, 1916.

¹C. F. Burgess and C. Hambuechen, *Electrochem. Industry*, Vol. 2, p. 183, 1904.

²O. P. Watts and M. H. Li, *Transact. Amer. Electrochem. Soc.*, Vol. 25, p. 527, 1914; *MET. AND CHEM. ENG'ING*, Vol. 12, p. 343, 1914.

³*Transact. Am. Electrochem. Soc.*, Vol. 19, p. 151, 1911; *MET. AND CHEM. ENG'ING*, Vol. 9, p. 267, 1911.

⁴*Jour. Iron and Steel Inst.*, Vol. 78, p. 134, 1908.

⁵*MET. AND CHEM. ENG'ING*, Vol. 12, p. 787, 1914.

⁶Palmaer and Brinell, *MET. AND CHEM. ENG'ING*, Vol. 11, p. 197, 1913.

⁷F. Fischer, U. S. Patents 992,951-2, May 23, 1911.

⁸Eighth Int. Cong. Appl. Chem., Vol. 28, p. 86, 1912; *MET. AND CHEM. ENG'ING*, Vol. 10, p. 620, 1912.

⁹U. S. Patent 984,703, Feb. 21, 1911.

phur dioxide which acts as a depolarizer. The electrolyte in the cathode compartment must be kept free of sulphur dioxide as the nascent hydrogen at the cathode would reduce it, depositing sulphur and contaminating the iron.

Part of the sulphur dioxide is oxidized to sulphuric acid at the anode. Ramage proposes to concentrate this liquor and distill off the acid. In this manner the products are both sulphuric acid and electrolytic iron.

In a later patent Ramage¹⁰ dissolves iron in a ferric liquor and electrolyzes the resulting ferrous liquor in a cell with a diaphragm and insoluble anode. The ferric liquor and free acids which result at the anode are again reduced and neutralized by the impure iron to be refined. This later operation is carried out in a separate tank and the resulting liquor filtered to keep the liquor clear in the refining tank.

In 1913 Boucher¹¹ received a patent in which the electrolyte is a solution of one or more ferrous salts, such as the sulphate or chloride. This is stirred in contact with the air before electrolysis to form iron-oxychloride which reacts with the hydrogen formed at the cathode and therefore acts as a depolarizer. The electrolyte is described as having a clear chestnut brown color and should not foam. During electrolysis, oxidation may be controlled by means of an adjustable opening in the cell cover. To reduce any ferric salts formed the electrolyte is passed over iron shavings in a separate vessel at a speed varying with the current density and with the amount of phosphorus in the cast iron anode. If this amount is 1 per cent, a circulation of four liters per hour per ampere is suitable. The concentration of the electrolyte is regulated in accordance with the amount of air supplied, but must be maintained constant during working; a suitable density is 35 deg. to 40 deg. Baumé. The cathode is rotated at a speed proportional to the current density; peripheral velocities of 100 to 120 meters per minute are suitable respectively for densities of 45 to 72 amp. per square foot (5 to 8 amp. per square decimeter). The temperature of the electrolyte is raised for high current densities but must not vary during electrolysis; it may be 50 deg. and 75 to 77 deg. C., respectively, for densities of 36 and 90 amp. per square foot (4 and 10 amp. per square decimeter). Iron thus obtained is annealed and is then ready for commercial use.

Reed's patent¹² covers both the manufacture of electrolytic iron and the making of sulphuric acid as a by-product. The electrolyte is a solution of iron sulphate. The anode is made of spongy lead which becomes sulphated as the electrolysis proceeds. By this method free sulphuric acid does not form in the electrolyte and there is no tendency for the cathode to dissolve. The resulting lead sulphate is treated electrolytically in a separate receptacle and the sulphuric acid recovered. It is claimed that this electrolytic iron is free of hydrogen.

In 1913 Cowper-Coles¹³ obtained a British patent in which he proposes to avoid exfoliation and brittleness in electro-deposited iron by suspending an iron sponge in an electrolyte used for refining iron. He claims to make iron tubes, ingots, sheets or produces pure iron directly from ores. The electrolyte is a concentrated solution of FeSO_4 or FeCl_2 which is electrolyzed, with or without a rotating cathode. As an example he states that a nearly boiling solution containing 1500 grams FeSO_4 per liter is used as electrolyte and under such conditions the current density may be as high as 40 amp. per square foot (4.5 amp. per square decimeter). The iron sponge may be gotten by roasting a sulphide or

other iron ore, with recovery of the sulphur and then reducing by gas.

Guillet,¹⁴ in a paper before the Iron and Steel Institute in 1914, described the process of the French Company "Le Fer" at Grenoble for making electrolytic iron. This company makes tubes, sheets, and material to be melted, the raw material being pig iron. A cathode revolving in a neutral solution of iron salts is used, the solution being maintained neutral by the circulation of the electrolyte over the surface of the iron. The bath also receives periodic additions of a depolarizing medium such as the oxide of iron. About 90 amp. per square foot (10 amp. per square decimeter) is the current density used.

An iron having the following average analysis is claimed to be produced after removing the gases:

	Per Cent
Carbon	0.004
Silicon	0.007
Sulphur	0.006
Phosphorus	0.003

Guillet states that it is possible to guarantee phosphorus lower than 0.010 per cent. When a current density of 90 amp. per square foot (10 amp. per square decimeter) is used the yield per kilowatt year is 2 tons of metal, including cost of power for accessory service. The iron is annealed at 900 deg. C., after which it possesses a high degree of ductility and can be readily worked. The current density used would depend upon the cost of power. By using a current density of 45 amp. per square foot (5 amp. per square decimeter) instead of 90, 4 tons of iron may be produced per kilowatt-year instead of two as the voltage drops one-half. Where the cost of power is high the current density should be low to secure higher efficiency. Guillet estimates that the total cost would be from \$30 to \$40 per ton in France according to locality. The cost in the United States would probably be near \$50 owing to higher cost of power, labor and materials.

The process described by Guillet is similar to that described by Cowper-Coles.

The various processes described for the production of electrolytic iron vary from the simple one used by Burgess to the complicated process of Boucher. While the more complicated methods use the cheaper pig iron and iron ore as sources of raw material, it is doubtful whether the cost of the finished iron is much less than in the simple refining process. The cost of rotating cathodes, removing slimes, solution maintenance, auxiliary apparatus, and the necessity of careful chemical regulation of the electrolyte minimize the advantage of low cost of raw material.

Uses for Electrolytic Iron

Electrolytic iron when deposited by the usual methods is brittle, due to the hydrogen present. In this form it can be easily broken into small pieces and even ground into a powder. By heating the iron to a red heat the hydrogen is driven off and the iron becomes ductile, the ductility increasing with the temperature of annealing.

Brittle electrolytic iron as deposited is highly soluble in acids,¹⁵ being much more readily soluble than zinc. Annealing the iron makes it become more resistant to acid attack than ordinary irons and steels. This property of the brittle iron has resulted in the suggestion that it be used for the manufacture of hydrogen by acid attack in place of zinc and other forms of iron.

The brittleness of the iron and its purity make it an ideal material for melting in crucibles, the hydrogen content having the additional virtue of forming a re-

¹⁰U. S. Patent 1,007,388, Oct. 31, 1911.

¹¹U. S. Patent 1,086,132.

¹²U. S. Patent 1,055,653, March 11, 1913.

¹³British Patent 12,638, May 31, 1913.

¹⁴Jour. Iron and Steel Inst., Oct., 1914, MET. & CHEM. ENGINEERING Vol. 12, p. 787, 1914.

¹⁵Burgess and Engle, Transact. Am. Electrochem. Soc., Vol. 9, p. 199, 1906.

ducing atmosphere. The brittleness also allows it to be readily broken into small pieces for introduction into the crucible.

The high purity of the iron makes it possible for it to be used in competition with Swedish iron and at approximately the same cost.

It may also be used for pharmaceutical purposes as a base for compounds of which iron is a constituent. Here again its purity is of value.

The much suggested use of electro-deposited iron for electro-magnetic purposes appears to be becoming of commercial importance. While the magnetic qualities of electrolytic iron seem to be superior to the commercial silicon irons its high electrical conductivity counteracts this favorable property.

Electrolytic iron also is used as a basis for scientific experimental work on the various properties of iron where the purest available iron is needed to secure the most accurate data. It is also used as a basis for "pure iron" alloys.

The materials that have been produced and which seem to give the most promise for direct production without further mechanical working are sheets and tubes. By producing these directly by deposition in such a manner as to not require further operations it would be possible to make thin sheets and tubes of great uniformity. In tubes having thin walls made by mechanical processes, these often vary in thickness and it is hoped that this defect will be overcome by making them electrolytically.

Effect of Addition Agents Upon the Deposition of Iron

The effect of addition agents upon the electro-deposition of iron has been studied by Watts and Li.¹² The solution used for experimental work contained 150 grams of $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, 75 grams $\text{FeCl}_2 \cdot 4\text{H}_2\text{O}$ and 120 grams $(\text{NH}_4)_2\text{SO}_4$ per liter with a specific gravity of 1.125 at 20 deg. C.

The addition agents giving the best results are given in the following table in order of excellence (amount given is per liter):

- 6.0 grams ammonium oxalate.
- 0.6 gram formin or hexamethylenetetramine.
- 2 drops phenol.
- 4 drops formalin.
- original solution.

These results show that the deposition of electrolytic iron may be improved by addition agents.

Detailed Estimate on Cost of Electrolytic Iron

The data of Tables I, II and III, covering in detail the cost of producing electrolytic iron on a large scale have been kindly furnished by Mr. C. F. Burgess. The plant is assumed to be 1000 kilowatt capacity with an output of 8640 tons per year of 360 days.

A current density of 10 amp. per square foot (1.1 amp. per square decimeter) is assumed and an energy consumption of 1 kw.-hr. for every 2 lb. of iron is also taken as warranted by past experimental work.

The most suitable anode material would probably be the crop ends of very mild steel, preferably the product of basic open-hearth furnace, or even better from concerns which are making the newer higher purity irons. These materials would have the advantages of low phosphorus and manganese and also of the other elements, which should have the least tendency toward sliming and consequent deterioration of the electrolyte.

It probably could be purchased at an average of \$15 per ton and would be worth \$20 per ton rolled into a form needed for use in the refining tanks. This figure would cover also the freight charges to the plant.

The estimate of Table II shows a total investment of \$128,360. This does not cover the total capital required. It does not include, for example, real estate investment other than that involved in \$1 per square foot (0.1 sq. m.) of building space; it does not provide for working capital or accumulated stock, nor does it provide for development work which would be necessary.

Table III gives the principal items of operating cost, which show that a figure of about \$10 per ton of refined iron is possible. In fact, this is believed to be a liberal estimate. It is larger than the figures given for the refining of copper, and in all probability the cost of refining iron would not be materially greater than that of refining copper. The operating costs, however, do not include interest on investment.

The cost of raw material is taken at \$20 per ton, thus making the cost of the electrolytic iron approximately \$30. If it would become necessary to use a low phosphorus rolled stock worth \$30 a ton the cost would be increased 33 1/3 per cent, which would limit the use of the refined iron.

TABLE I—ESTIMATE ON ELECTROLYTIC IRON PLANT

Power consumed in tanks.....	1,000 kw.
Output refined iron.....	24 tons per day (8640 tons per 360 days)
Refining Tanks—	
Made of 2 in. (5 cm.) cypress lumber, re-enforced.	
Size, 6 ft. 6 in. (200 cm.) long; 3 ft. 6 in. (105 cm.) deep; 3 ft. 8 in. (110 cm.) wide, outside.	
Number, 840.	
Floor space per tank, 50 sq. ft.	
Total floor space, tank room, 42,000 sq. ft.	
Cost of each tank—	
Lumber, 190 ft., at 5 cents.....	\$9.50
Labor and re-enforcement.....	9.50
Fittings, drains, pipings, and conductors.....	11.00
	\$30.00
Amount of iron in each tank—	
11 anodes 3 ft. (90 cm.) x 2 ft. (60 cm.) x 1 in. (2.5 cm.) thick.....	2,530 lb. (1,150 kg.) per tank
10 thin sheet cathodes.....	70 lb. (32 kg.) per tank
	2,600 lb. (1,182 kg.) per tank
2600 lb. at 1 cent = \$26.00.	
Electrolyte, at 33 cents per cu. ft. = \$23.00	

TABLE II—COST OF ELECTROLYTIC INSTALLATION

840 tanks, with fittings, at \$30.....	\$25,200.00
Electrolyte 840 x \$23.....	19,320.00
Iron under treatment.....	None
840 x 2600 lb. = 1092 tons at \$20.....	21,840.00
Total cost of tanks.....	\$66,360.00
Cell room—42,000 sq. ft. (3800 sq. m.) floor space.....	42,000.00
Additional equipment—	
Traveling cranes, pumps, storage tanks, purifying tanks, etc.	20,000.00
Total investment inside switchboard.....	\$128,360.00

TABLE III—OPERATING COSTS.

Power, delivered to cells, 1000 kw. at \$50.....	\$50,000.00
Engineering and superintendence.....	7,000.00
Labor, 20 men at \$800 per annum.....	16,000.00
Depreciation—	
Tanks and fittings: 15 per cent on \$25,200.....	\$3,780.00
Electrolyte: 10 per cent on \$19,320.....	1,932.00
Iron under treatment.....	None
Building: 5 per cent on \$42,000.....	2,100.00
Accessories: 10 per cent on \$20,000.....	2,000.00
	\$9,812.00
Miscellaneous repairs, etc.....	10,000.00
	\$92,812.00
Total cost of 8640 tons = \$92,812.00	
Total cost per ton = 10.75	

The Elyria Enameled Products Co., Elyria, Ohio, manufacturers of glass-enameled apparatus for use where resistance to acid and alkali is required, will shortly open an office in Chicago. The representative for the Chicago district is Mr. J. E. Simpson, who may be addressed temporarily in care of the Morrison Hotel, Chicago. Announcement of the permanent office address will be made later. In the Pittsburgh district the company is represented by Mr. W. E. Gray, Jr., with an office at 1237 Oliver Bldg., Pittsburgh. The maintenance of these district offices will enable the company to handle its business to better advantage and improve its service.

¹²Transact. Am. Electrochem. Soc., Vol. 25, p. 527, 1914; MET. AND CHEM. ENG'G, Vol. 12, p. 343, 1914.

Synopsis of Recent Chemical and Metallurgical Literature

Pyritic Smelting

Feeding Blast-Furnaces in Pyritic Smelting.—From the presidential address of Mr. ROBERT C. STICHT in the *Proceedings of the Australasian Institute of Mining Engineers* we take the following abstract:

"The most important operation in connection with our work is the feeding of the furnaces. This is done with special care, though it still remains rather rough work, in a sense. As the throat is fiery, it is not approachable, and the fine work done in the olden days, when throats were cold and the blast low, cannot be carried out now.

"It is being conceded that the manner in which the modern copper blast-furnace is fed, by simply sliding the charge into it *en masse* over an inclined plane on the long wall, is too crude to do justice to the requirements of good smelting. It certainly shows itself to be a mistake in pyrite smelting, and the mechanical features, which make it attractive to the metallurgist who is only bent on saving the small labor attaching to the actual feeding, are blinding him to the troubles and costs which the bad feeding entails, and which are not so obvious. It is quite possible to deliver the materials to the furnace by the same means (electric train) in both cases, but they should not be dumped in helter-skelter. Whatever may be the case with ordinary blast furnaces, it is a fact that pyrite furnaces, on which this careless method of charging is used, are not doing good or really economical work, as is evidenced by their low-grade mattes and short campaigns. It is impossible, in the first place, under the conditions of wholesale delivery, as mostly arranged nowadays, to do close work, such as running each furnace individually, and the result is that the nest of furnaces is run as one unit. This obliges one to average the composition of the charges practically down to the mean requirement of the nest, and to forfeit the advantage of the superior work which can be done by the furnaces which are in better trim. Those which are not in good trim cannot, of course, be forced to do good work, and a mediocre standard, embracing all the furnaces in the nest, is the only recourse. Dump feeding, whether from the side or from the top, treats the operation as if it had to be got over as quickly as possible, and as if the amount of care required were negligible. Our experience proves that this is not so. For a lengthy period we have, moreover, ourselves used an automatically discharging dump car, which dropped a whole charge at once onto the column from above, but the furnace did not smelt well, and the method was discarded, because too little control could be exercised over the feeding. The furnace even had a low tonnage capacity, in consequence of the tightening of the column by the falling charges.

"The feeding at Mount Lyell is done on each long side of the furnace off a horizontal charging plate, which reaches into the shaft with a slight overhang. Onto this plate the charge constituents are tipped, out of end-discharging hand-carts, in a narrow pile, as long as the opening and parallel to the furnace, so that when pushed over the edge of the plate, the materials drop so as to cover one-half of the top of the column on each side. The materials drop gently over the edge of plate, and do not shoot across to the other wall and rebound. A special device is used for pushing the substances in, which consists of a line of hinged steel plates inclined forward and parallel to the furnace, which is fixed to a frame embracing both sides of the furnace, and is actuated by means of a hydraulic cylinder. The movement is to and fro, the two sides of the furnace

being fed alternately. The pusher plates ride freely, on the return stroke, over any matter left on the charging plates, but the latter are swept quite clean on the forward movement. The charge constituents are not delivered mixed together, but singly, one after the other, and are pushed in separately. No special merit is claimed for this device, but it certainly has simplified and perfected the feeding. It is possible to do with it all that can be done by hand feeding, and, when particular places on top of column have to be specially humored, the feeder still can do so by hand if he likes with the long-handled shovel, using the blade inverted. The distinction between coarse and fines can be maintained as with hand feeding, the respective stuff being directed to be dumped by the wheeler in front of the right spot, or the separation can be done by the feeder on the plate, with a few strokes of the shovel in the long heap, before pushing. The placing of the materials onto the charging plates is under the immediate direction of the feeder, and he is held responsible for the condition of the throat. If the throat is properly nursed, the rest of the ore column in action will take care of itself.

"A good deal depends upon the placing of the coarse or fines at the proper place on top of charge, and in connection therewith the proper overhang of the charging plate is of some moment. Notwithstanding that all materials fall almost vertically off the edge, the fines fall closer to the wall than the lumps and the exact place where the latter assemble depends upon the vertical distance from charging edge to top of column. The furnace can be fed with a gullet down the center line, or with a hillock along that line, or with more than one gullet or furrow. The overhang distance has an effect on these points, and a device has been worked out permitting of instantaneously changing the amount of the overhang, but it is not really being used. It would lead too far to go into further details. Ordinarily speaking, for normal running the practice is to distribute the materials evenly over the full top of the column. The latter is not visible from the charge openings, as these are made only high enough to allow the charge to be shoved in (14 in. by 18 ft. 6 in.), so that the indraft of air and the back-leak of fumes may both be minimized. There are no doors on the charge openings. The feeder observes the state of affairs at the throat through a lidded opening in the swinging doors at each end of the superstructure. The barring of the furnace throat is done through these doors only.

"The gases must be seen issuing evenly from all over the top of column, with only slightly more coming up along the walls. The pieces of charge, of course, remain black on top of column for some time after charging, and those of the underlying layer show a dull red heat. There is no appearance of high incandescence. A perfectly black top would soon lead to the formation of crusts. The general temperature right over the top should not be much higher than suffices to ignite the subliming sulphur, and the top must be kept down to bring this about, but not much lower than this, if possible. There should be no blow-holes. Dead, glowing red places are indicative of the formation of accretions, or wall crusts, and are not permitted to grow too much. They would eventually close the furnace throat, and, in any case, they upset the distribution of the blast. They are attended to at once by feeding some of the pyrites on charge onto them and keeping the silica off. If accretions have formed all along the walls, then most of the feeding is done along the center line of throat. When the throat is working properly there is a constant crackling noise from the decrepitating of the pyrites, etc.

"There is a fixed order in which the constituents of the charge are fed in, which is never varied. The coke is first put in, then all the pyrites, then the silicious ore, followed by the limestone, and finally the slag. The pugged flue-dust and the barren silica are put in at intervals, as dictated by the supply, or as required by the furnace conditions. They are not made regular constituents of the charge. The coke, being small in amount, scarcely falls so that it covers the whole of the respective half-surface of the top, but comes nearer the walls. The other materials, as remarked, are each equally spread all over the top when things are normal. A constant source of derangement are blow-holes, which interfere by leading the blast preponderatingly to themselves and robbing it from the rest of the furnace, thus disturbing the uniformity of the focus action. They are cured by filling them up with the 'dry' portions of the charge, i.e., North Lyell ore, slag, silica and limestone as a general rule."

Classifying

Combined Hydraulic and Mechanical Classifier.—In a paper prepared for the forthcoming Arizona meeting of the American Institute of Mining Engineers Mr. M. G. F. SOHNLEIN describes a combination classifier, which he devised to produce results that otherwise could not be accomplished satisfactorily. His problem was to prepare a pulp of tin ore for jigging. A Richards vortex classifier had been in use, but it clogged badly from fine vegetable matter in the water, and considerable slime was sent to the jig. Later a hydraulic classifier of the Anaconda type was provided, and its work was satisfactory if sufficient hydraulic water was used, but under these conditions a good deal of material that should have gone to the jig was carried into the overflow. If less hydraulic water was used, the sand product contained some slime, and the jig separation was not quite satisfactory. The desideratum was to obtain separation of part of the sand in the pulp under hindered-settling conditions without diluting fine material with too much water. In order to accomplish this, the apparatus shown in Fig. 1 was designed, consisting of a narrow wooden trough, in which the paddle wheel revolves. Details of the classifier can easily be gathered from the drawing. The tips of the blades are protected by $\frac{1}{4}$ -in. iron strips fixed with two countersunk rivets. The strips last about four

months and are replaced at small cost. The blades are cut from $\frac{1}{4}$ -in. plate and bent in the fire. They are fixed to the rim of the pulley by three 1-in. by $\frac{3}{8}$ -in. machine bolts. The holes in the rim and those in the blades are bored from a template, and spare blades are kept ready so that but little time is lost in making renewals. The wheel is driven at the rate of 3 r.p.m. by a simple worm gear—in this case taken from an old vanner—which is directly belted to a line shaft. The feed is introduced into the trough near the bottom at O, after having been submitted to hydraulic classification in the pyramidal attachment P, in which an ascending current of water flows out of the pipe N. Consequently the material which is undesirable in the jig feed is floated off with the use of less hydraulic water than needed in an ordinary hindered-settling classifier because the slime that comes with the sand into the trough is separated by the paddle-wheel and flows over at A. It is evident that classification in the hydraulic pocket does not entirely take place under hindered-settling conditions, because in that case the sand treated by the wheel could not contain any slime. The amount of hydraulic water used is such that the dilution of the overflow does not exceed the required density and therefore the classification cannot be perfect. However, the most objectionable factor, namely the presence of slime in the jig feed, is to a large degree eliminated by the subsequent action of the paddle-wheel. The moisture in the sand discharged by the wheel can be regulated in two different ways, (1) by raising the level of discharge, and (2) by increasing the distance between the tips of the blades and the discharge.

The discharge level of the sand product can be varied by inserting strips of wood of different heights into the slots marked S. To obtain practical results the sand is discharged at a point $1\frac{1}{2}$ in. above the overflow with 50 to 55 per cent moisture, but with the level of sand discharge raised to $2\frac{1}{2}$ in. above the overflow, and the discharge edge spaced from the wheel as shown in the drawing, the product contains but 30 to 35 per cent moisture, but under these conditions the capacity decreases out of all proportion. If the machine is overfed, the sand piles up so high at the discharge that part of it remains lying on the paddles, and falls back into the trough at the other side, finally choking the classifier.

A spray is provided to remove the adhering grains of sand from the blades of the wheel, and after having cleaned the blades, the water falls on the pile of sand lying in front of the wheel and gives it a final wash. The slower the wheel revolves the cleaner will be the sand product, because then every blade brings up slightly more sand than it can deliver, and part of the material falls back into the trough to be shoved up again by the next blade. Therefore the sand is repeatedly turned over before being discharged, which materially assists in removing the slime.

The classifier can easily handle 60 tons of dry pulp with a specific gravity of 3.5 to 3.8 per twenty-four hours.

The jigging practice has considerably improved with the better adapted feed, and the grade of the concentrate has been raised from 66 per cent metallic tin to an average of 70 per cent and more.

Antimony

Antimony Production in South China.—In our issue of March 15 (page 374) we gave an account of a paper on antimony production in Hunan Province, South China, by A. S. WHEELER. In the *Bulletin* of the Institution of Mining and Metallurgy of March 16, 1916, contributory remarks are given to Mr. Wheeler's paper, which supplement this information.

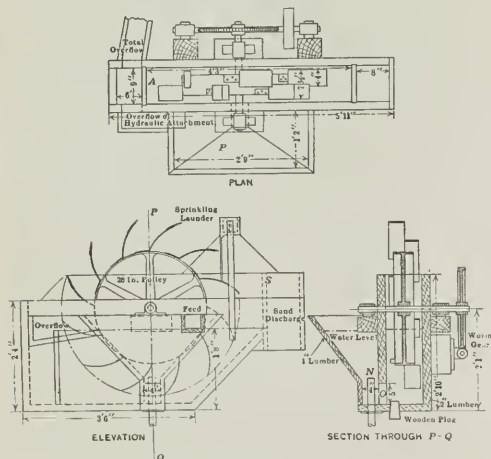


FIG. 1—COMBINED HYDRAULIC AND MECHANICAL CLASSIFIER

Mr. W. R. SCHOELLER says: The fact that English regulus fetches a higher price than Chinese metal of the same purity must be ascribed to the antiquated methods of a trade which prefers to be guided by the brand of metal rather than adopt the up-to-date methods of sampling and assaying. The quality of Chinese antimony is not only due to the purity of the ores, but also to the superiority of the Herrenscheidt process over the precipitation method. It must be said, however, that the volatilization process is better adapted to the treatment of low-grade ores and liquation residues, as the excess of gangue prevents fritting of the fusible sulphide. This explains why English smelters, who have to rely for their supply on imported (i.e. high-grade) ores or crude, are using precipitation by iron, while in France the smelting works are situated in close proximity to the mines, the whole output of which (chiefly low-grade ore) is treated by the volatilization process. The enormously increased demand for antimony created by the war is bringing about a revolution in the metallurgy of antimony, the more important English smelters discarding graphite crucibles in favor of water-jacketed blast furnaces, while retaining the principle of iron precipitation. The change may be expected to prove lasting, as enormously high working cost constitutes the radical defect of the old process.

Mr. ERNEST A. SMITH says: Mr. Wheler's paper is a welcome contribution to the metallurgy of antimony, not only because the Chinese have practised the metallurgical arts from remote antiquity, but also because the process described is the one by which a large proportion of the world's supply of antimony is obtained at the present time, China having become, within a few years of the opening up of her mineral resources, the foremost producer of antimony. From an economic standpoint the liquation of antimony sulphide in pots as practised by the Chinese leaves much to be desired, and it is of interest to note that the Hua Chang Antimony Company has introduced the Herrenscheidt volatilization process, which shows that those responsible for the production of antimony in China are not opposed to the introduction of modern metallurgical processes.

Although the liquation process is very simple in manipulation, experience proves that the crude antimony obtained, which varies from 68 to 73 per cent antimony, is almost entirely dependent on the temperature employed in the operation. Gowland, in his "Metallurgy of Non-Ferrous Metals," has pointed out that when the temperature is much above a red heat—the melting point of Sb_2S_3 —the sulphide is volatilized and the product has not the dark iron-grey color required in commerce, but a red tint, and is difficult to sell.

It was formerly assumed that crude antimony was pure, unaltered sulphide, but the recent researches of Schoeller have shown that Chinese crude is a more complex product than was generally supposed.

The following three typical analyses of Chinese crude antimony by Schoeller show that the antimony is present in excess of the theoretical amount, 71.43 per cent demanded by the formula Sb_2S_3 , and the sulphur necessarily below theory, showing that all the antimony is not combined with sulphur.

Complete analyses also disclose a deficiency which is attributed to the presence of oxygen.

ANALYSES OF CHINESE CRUDE ANTIMONY (SCHOELLER).

	1.	2.	3.
	Per Cent	Per Cent	Per Cent
Antimony	71.60	71.70	73.56
Sulphur	21.60	24.92	22.45
Iron	0.82	0.14	0.70
Insoluble	0.41	0.24	0.05
Arsenic, zinc, copper, lead	0.16	0.07	...
	94.59	97.07	96.76

These differences Schoeller attributes to the presence of antimonious oxide (Sb_2O_3) and a small amount of metallic antimony. The presence of metallic antimony is of special interest, as it seems very probable that the reaction between antimony oxide and sulphide ($Sb_2S_3 + 2Sb_2O_3 = 6Sb + 3SO_2$) takes place, though to a very limited extent.

Mr. WM. F. COLLINS said: The Hua Chang Company is to be congratulated upon its enterprise in establishing an important smelting industry, which is supplying the world with a large supply of antimony. It will be remembered that the standard textbook on antimony was written by Mr. C. Y. Wang, a Chinese student, who went carefully into the metallurgy of antimony in Europe some years ago, and introduced up-to-date processes into China.

Mr. Wheler states that analyses of the various brands of antimony on the market show that the Chinese product is equal in quality to European brands, though previous to the war the latter were selling at 6l. or 7l. per ton more than the Chinese. As British firms guarantee their antimony at greater purity than do the Hua Chang Company, it would appear that Mr. Wheler's remark, though interesting as a statement, is inaccurate as to fact.

It is admitted that the consumers of metal in this country (England) may be far behind those of Germany and the United States, and are so conservative in their methods that they often fail to have assays made of metals supplied to them. It will be found, however, that so great is the esteem of our acute Transatlantic cousins for British brands that they are willing to pay something over 50l. per ton more for standard British than for Chinese antimony. Such appreciation of the British product may be temporary and accidental. It appears to indicate that the Chinese metal is suffering from a state of affairs which has caused Chinese tea, silk and cotton to fall considerably from positions once supreme as to commercial possibility.

Recent Chemical and Metallurgical Patents

Caustic Soda, Chlorine and Chlorate

Improvements in Mercury Cathode Cell.—A method of forming a mercury cathode in an alkali chloride cell, which has for its object the overcoming of some disadvantages of alloying the sodium and mercury, is patented by KARL HEINEMANN of Pirna, Germany. Fig. 1 is a longitudinal section of a cell and Fig. 2 shows two sectional views of the bottom plate on an enlarged scale. The cell consists of a lower part or frame *a* and an upper part *b*; between both parts the bottom plate *e* is squeezed by means of a flange *c* and bolts *d*. The part *b* is lined with an insulating layer *f*. The bottom plate *e* is a little inclined from the left to the right, so that the mercury entering by the pipe *g* slowly flows to the other end of the cell over the bottom plate *e* and

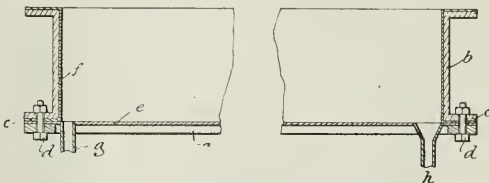


FIG. 1—MERCURY CATHODE CELL

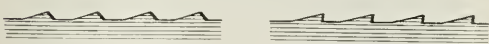


FIG. 2—BOTTOM PLATE

is discharged through the pipe *h*. The anode which would be suspended above the bottom plate *e* in a salt solution is not shown, and likewise the cover locking the top of the electrolyzer and containing the electric terminal for the anode and the pipe conducting away the chlorine.

The bottom plate *e* is provided with projections which are shown on an enlarged scale in the second diagram. No plain bottom plate is employed even with nearly horizontal surfaces of the cathode, but a bottom plate is used on which the mercury current constantly meets projections of small height extending preferably over the whole bottom plate at a right angle to the direction of the mercury current. They may have the form of ribs the height of which amounts to about 0.5 and the interval between which amounts to 1 to 1.5 mm. The effect of these impediments consists in that the mercury is dammed or banked up before them, whereby a most effective and intimate mixture of the amalgam and the mercury is stated to be produced and an output nearly approximating the theoretical amount is obtained. The damming effect may be increased by making the slope of the impediments on the side directed against the mercury current more inclined than on the opposite side, or by making them hang over on the side directed against the mercury current (1,176,551, March 21, 1916).

Caustic Soda and Chlorine Electrolytic Cell.—In a patent of ARTHUR E. GIBBS of Wyandotte, Mich. (assigned to Pennsylvania Salt Company), a description is given of a new form of the "Gibbs cell." Reference is made to his former patent No. 874,064 Dec. 17, 1907, a review of which was given in our Vol. VI, p. 32 (1908). The cell is in use at Wyandotte, Mich.

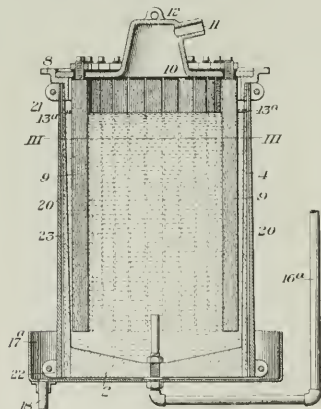


FIG. 3—ELECTROLYTIC CELL

In the present patent a new form of cathode and a new method of conducting the flow of electrolyte through the cell are the main features. The improved form of cell is shown in Fig. 3, in which 2 designates a bottom of resistant material. The cathode is composed of a series of segments 20, fitted together to form a complete cylinder and held in place by the top and bottom clamping rings 21 and 22. The segments are made of castings, and their inner faces are vertically corrugated, as shown in 23, forming a series of vertical channels between the cathode and the diaphragm 4. These channels are partially filled by the embedding of the corrugations in the diaphragm. Vertical channels are left, however, through which the caustic formed can flow

down to pan 17a. A feature of the cell is the perforations at 13a through the diaphragm to allow of the flow of electrolyte from the anode chamber down over the cathode, in order to wash away the products of electrolysis. At times the diaphragm becomes somewhat clogged, and this auxiliary flow, independent of the diaphragm, helps to keep up the efficiency of the cell in this case. This overflow method can also be applied to the form of cathode with projections as described in the former patent mentioned above. The feed pipe 16a for electrolyte connects with a cup, which can be adjusted so as to maintain the desired level in the cell. The anodes 9 are carbon rods forming an annular unit fastened to the top piece 8. (1,176,540-1, March 21, 1916.)

Manufacture of Chlorates and Perchlorates of Alkali Metals.—A process for the manufacture of chlorates and perchlorates, which, to some extent, is a combination of previous processes, is patented by ARTHUR E. GIBBS of Wayne, Pa. Chlorates have been chiefly made by either passing an excess of chlorine through milk of lime and separating the chlorate produced or by electrolyzing a chloride in a cell without a diaphragm and separating the chlorate thus produced. The present process, which lays its chief claim for distinction to the formation of a solution containing more chlorate than chloride for concentration, is shown diagrammatically in Fig. 4.

When sodium chlorate is the product desired the method is carried out as follows: A solution of sodium chloride is supplied to the feed cup 6 from whence it passes into the anode compartment of the cell 2 and is electrolyzed. This cell was described in our Vol. VI, page 32 (1908) (see also the above account of patent No. 1,176,540). The caustic or cathode liquor is drawn from the cathode compartment of the cell by means of the pump 9, and flows into the tank 10, from which it overflows into the tank 13, and thence into the tower 17. In passing through this tower it meets an

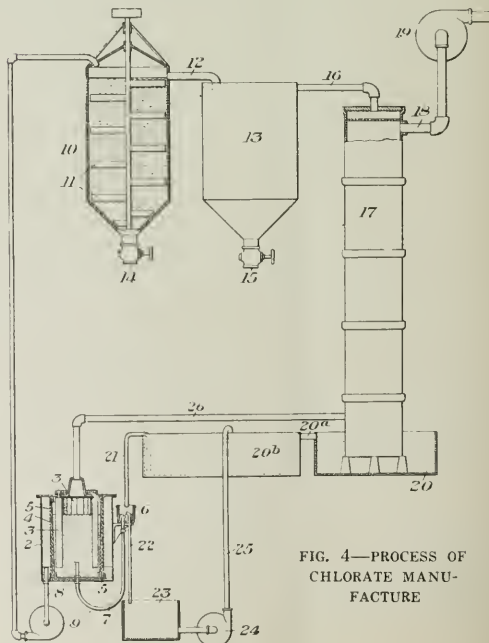


FIG. 4—PROCESS OF CHLORATE MANUFACTURE

ascending current of chlorine gas delivered from the pipe 26 from the anode compartment. Hypochlorite of soda is formed, and this is converted into chlorate by the excess of chlorine which exists near the bottom of the tower. If the conversion to chlorate is not otherwise complete, artificial heat may be supplied in any suitable manner. In the event of any unconverted hypochlorite passing into the tank 20b and thence to the cell 2, it is immediately oxidized in the anode compartment of the cell. The overflow from the feed cup 6 falls into the tank 23 and is returned by the pump 24 to the tank 20b. During the operation sodium chloride is supplied to the tank 10 to keep the solution saturated to as high a degree as is practicable with that salt. After the liquors have circulated through the system a number of times, the chlorate gradually increases in amount and the liquor is then removed and concentrated for the recovery of the chlorate. The salt which separates out can be returned to the system. Impure salt is usually used, and this causes a precipitation to take place of calcium and magnesium salts in tank 10, at the expense of caustic or alkali carbonate. This is an advantage in that it provides an excess of chlorine in the absorption tower, which is necessary for conversion.

Potassium chlorate can be conveniently made by using a potassium chloride electrolyte, or a mixture of potassium and sodium chlorides in solution, or by adding potassium chloride to the sodium chloride electrolyte above described. Double decomposition between the sodium chlorate and potassium chloride takes place and the less soluble potassium chlorate separates out. The chlorate of potash may be removed either at 14 or 15. It is in the form of a sludge, and may then be purified in any usual way, as by placing it in a centrifuge to separate the caustic liquor from the chlorates and from the insoluble mud precipitated from the commercial chloride which is added at this point. The sludge can then be purified by a re-dissolving, settling and crystallizing, or concentrating by well-known methods.

By circulating the liquor through the cell a number of times, the proportion of chlorate to chloride is greatly increased, and the solution going to the concentrators can thus be made to contain more chlorate than chloride. As the reaction between caustic and chlorine to produce chlorate is such that five molecules of chloride are produced to one molecule of chlorate, this feature is of great importance. The necessity of handling a large amount of chlorid for a small production of chlorate has caused the commercial abandonment of many other methods which have been tried. The operation can be carried on at temperatures about 40 deg. C. without causing undue corrosion of the electrodes, and a further advantage is that the diaphragm filters any carbon which might become detached from the anodes, and thus prevents it from contaminating the chlorate and causing increased danger in grinding. The addition to the electrolyte of chromic acid is stated to be unnecessary. (1,173,346, Feb. 29, 1916.)

Other Electrolytic Processes

Production of Peroxides by Electrolysis.—A process for the production of peroxides by electrolysis at atmospheric pressure is patented by Dr. WALTER WEBER of Düsseldorf, Germany (assigned to Henkel & Co., of Düsseldorf, Germany). It is stated that formerly it has been found impracticable to produce hydrogen peroxide by the electrolysis of water containing oxygen gas, although one patent was taken out producing it at increased pressure. In the present process peroxides are produced under ordinary pressure by preventing the accumulation of hydrogen peroxide within the electrolyte. This is done by precipitating the hydrogen peroxide

by adding a soluble compound to the electrolyte. A temperature of 0 deg. C. is used, and in order to further increase the output stabilizing compounds such as starch, gelatin, boric or phosphoric acid are added. The process, according to the invention, lends itself to the production, among others, of peroxides and peroxide-hydrates of the metals of the alkaline earths, such as barium peroxide and calcium peroxide, or of magnesium peroxide and aluminium peroxide, as well as of salts of the perboric acids, such as sodium perborate.

Example: 20 g. borax, 4.2 g. sodium hydrate, and 22 g. sodium sulphate or 30 g. sodium phosphate ($\text{Na}_2\text{HPO}_4 \cdot 12 \text{H}_2\text{O}$) are dissolved in 1000 cc. water. This solution is electrolyzed with a cathode consisting, for instance, of amalgamated silver and with an anode consisting of platinum or lead and separated from the cathode space by a diaphragm-tube, oxygen being continuously introduced and the solution being vigorously stirred by mechanical stirring apparatus and kept at approximately 0 degree C. by placing the electrolytic cell in a refrigerating solution. Pure sodium perborate containing 10.3 per cent of active oxygen is obtained, the output per unit of current employed being very high. Borax and sodium hydrate are continuously supplied afresh, as the sodium perborate is removed, this removal being a continuous one also. The density of current at the cathode is, for instance, 0.2 amp. per 100 sq. cm. (1,169,703, Jan. 25, 1916.)

Electro-Osmosis

Apparatus for Electro-Osmosis.—In apparatus for separating the finely divided particles of clay, kaolin, etc., by osmosis there has been generally no means for preventing the mixing of fresh solution with impoverished solution. A process

which aims to overcome this disadvantage is patented by HANS ILLIG of Frankfort-on-the-Main, Germany (assigned to Gesellschaft für Elektro-Osmose of Frankfort-on-the-Main, Germany). The method is shown in Figs. 5 and 6. The suspension to be treated is forced up through pipes *a* by means of vanes *d*. These vanes deliver the solution to the chamber *f, f*, from which it is forced through the perforated cathode *c*, against the revolving cylindrical anode *b*,

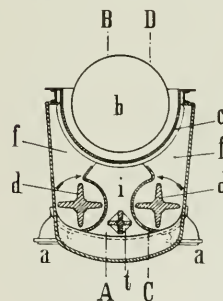


FIG. 5—ELECTRO-OSMOTIC APPARATUS

as is usual in these machines. The suspension is impoverished by the anode *b*, the particles clinging to the anode and being removed by suitable scrapers. Those particles which do not settle on the anode, or are repelled by the cathode, flow away through the middle chamber *i*.

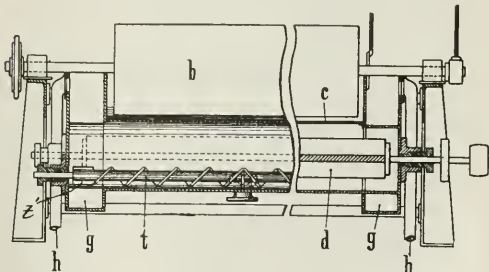


FIG. 6—ELECTRO-OSMOTIC APPARATUS

This middle chamber is connected to two auxiliary chambers, *g, g*, and has a shaft carrying vanes *t* to convey the solution to these chambers. In another form of the apparatus no middle chamber is provided, the impoverished solution flowing off through gutters on the sides. (1,174,946, March 7, 1916.)

Electro-osmotic Tanning Process.—A process of purifying tanning extracts and simultaneously impregnating materials to be tanned is patented by BOTH SCHWERIN, of Frankfort-on-the-Main, Germany (assigned to Elektro-Osmose Aktien Gesellschaft of Frankfort-on-the-Main, Germany). A cross section of the apparatus illustrating this process is shown in Fig. 7. A receptacle *a* is divided into compartments 1, 2a, 2b, 3 and 4, as shown, by diaphragms 5, 6 and 10, and leather

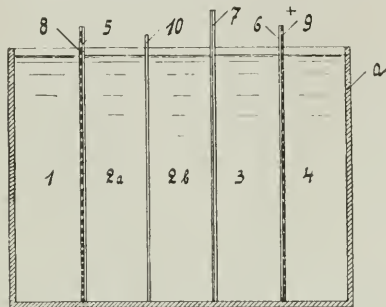


FIG. 7—ELECTRO-OSMOTIC TANNING PROCESS

7, to be tanned. Diaphragms 5 and 6 are made of parchment paper, or viscose. Diaphragm 10 "should be a positive" and can be made of leather. Electrodes 8 and 9 are perforated and of the polarity indicated. The leather 7 to be tanned can be placed in a frame or other support. All these divisions are filled with water, with the exception of space 2a between the cathode diaphragm 5 and the positive diaphragm 10, in which space the tanning extract to be purified is put. When the circuit is closed, the basic impurities of the extract go through the cathodic diaphragm 5 into the cathode space 1, whereas the acid impurities, which are not as great in amount as the basic, go through the positive diaphragm 10 into the space 2b, from there through the hide 7 and finally through the anodic diaphragm 6 into the anode space 4. When a certain purification of the extract is thus obtained, then the tanning material of the extract goes through the diaphragm 10 and accumulates in pure form in the space 2b, and thence on account of the current it passes through the leather and appears in the space 3, from which the solution can be withdrawn. The leather is thereby tanned. Diaphragm 6 is chosen of such material as for instance, parchment paper, that the tanning extract cannot pass into the anode space 4. (1,174,903, March 7, 1916.)

Electric Furnace Processes

Electric Furnace for Producing Phosphoric Acid.—An electric furnace for treating phosphate rock for the production of phosphoric acid is described in a patent of INGENUIN HECHENBLEIKNER of Charlotte, N. C., assigned to the Southern Electrochemical Co. (which operates an experimental plant in South Carolina for the production of nitric acid from the air).

In the manufacture of phosphoric anhydride from which phosphoric acid is made suitable quantities of natural phosphate rock, silicious material and carbon are mixed together and fed to the electric furnace. The heat of the arc and the resistance heat developed will

expel phosphoric acid and phosphorus vapor from the furnace mixture, leaving a calcium silicate slag which as it accumulates will overflow through a slag trap spout. The furnace is shown in sectional elevation in Fig. 8. It consists of three sections; the lower or hearth section A, the tapering section B, and the outlet elbow C. When originally constructed the bottom section has no lining, but water jackets on the outside

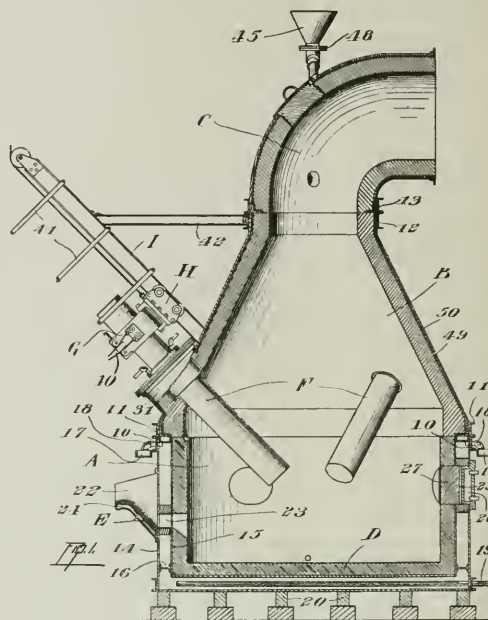


FIG. 8—ELECTRIC FURNACE FOR PHOSPHORIC ACID

cause a portion of the slag to freeze on the first charge, thus forming a lining of calcium silicate slag. This is stated to be the only lining which will resist the phosphoric acid. The tapered section is not water-cooled and carries the electrodes of which there are three (only two shown in drawing). The manner of holding the electrodes can be understood from the drawing. The slag overflow trap is shown at E. The phosphorus and phosphoric anhydride expelled from the charge are collected in absorption apparatus (see Patent No. 1,112,211, Sept. 29, 1914, granted to above).

It is stated that a very careful control of the heat is necessary and that the tapered part of the furnace above the electrodes preheats the charge which is introduced through 45, and also lessens the area of the ascending gases, thereby effecting a uniform degree of heating. Overheating of the charge will cause a distillation of silicon and silica compounds which are detrimental (1,173,960, Feb. 29, 1916).

Fixation of Atmospheric Nitrogen

Process of Nitrogen Fixation.—A process of nitrogen fixation is disclosed in a patent of HERBERT R. MOODY and SAMUEL A. TUCKER of New York City. In Fig. 9 is shown a furnace in which this process may be carried out. The furnace structure suitably lined is indicated at J. The heating chamber D is filled through hopper E with a charge of an oxide or carbonate of an alkaline earth metal (such as calcium or barium) or the oxide of carbonate of lithium, together with carbon in the proportions used in the usual production of car-

bides. This mixture is heated by electrodes *D* by either direct or alternating current to a temperature above the dissociation temperature of the carbides of the barium, calcium, or lithium used. Nitrogen is introduced ordinarily through *H*, but may be introduced through one electrode as at *A'*. The volatile products from the charge and the nitrogen introduced unite to form nitrides of calcium, barium or lithium and also

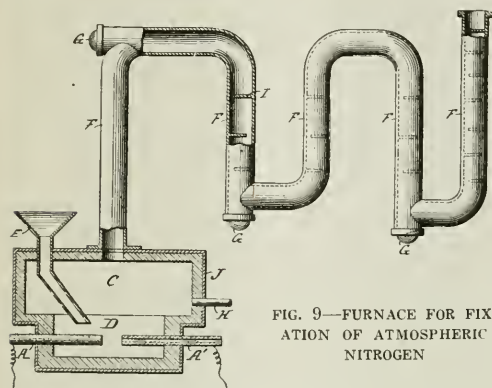


FIG. 9—FURNACE FOR FIXATION OF ATMOSPHERIC NITROGEN

cyanides and cyanamides of the metals. The products pass off through flues *F*, which constitute a condenser.

Instead of using the charge mentioned above, the previously prepared carbide may be used. Atmospheric pressure is used in the process and all operations, that is, carbide formation, carbide decomposition, and nitrogen fixation are all carried out in a single apparatus. It is stated that the products evolved by the dissociation of the carbide are carried into the atmosphere of nitrogen in an extremely fine state of division, so that a most intimate mixture is obtained. By adding calcium chloride to the charge, equivalent to 5 per cent of the carbide producible, it is claimed that the total amount of nitrogenous product obtained is doubled. (1,175,007, March 14, 1916.)

Electric Furnace Process of Nitrogen Fixation.—A process of nitrogen fixation, using an electrical resistor of a mixture of finely divided iron, carbon and sodium carbonate, is described in a patent of JOHN E. BUCHER of Coventry, R. I. (assigned to the Nitrogen Products Company of Providence, R. I.). A charge of the above ingredients forms all of the necessary constituents except nitrogen for the production of cyanogen compounds, such as cyanides or cyanamids. The charge is mixed and briquetted under pressure after adding sufficient water, or the mixture may be heated slightly above the melting point of the alkali carbonates, with the exclusion of air, and briquetted under pressure. This preheating is of great advantage. These briquets form the resistor column in an electric furnace, and a current of nitrogen is passed up through the charge while heating is going on, forming carbon monoxide and cyanides, which pass off as gases through an outlet in the top of the furnace.

In heating such a charge of iron, carbon and sodium carbonate, by external means it is stated that the charge conducts heat slowly, hence becomes unevenly heated, and the process is very seriously retarded by the slow heat penetration. Other disadvantages are encountered which are claimed to be overcome by the internal heating with the use of the charge as a resistor. When cold, this resistor is an insulator because of the solid sodium carbonate present, but it is stated that when heated to 800 to 1000 deg. C. its resistivity increases

so greatly that it is a fairly good conductor. It becomes plastic, and when nitrogen is forced through the endothermic cyanide reaction takes place, the iron acting as a catalyzer.

In Fig. 10 the furnace is shown as made of two concentric iron cylinders 1 and 2, the space between being filled with kieselguhr, ashes, or other refractory material 3. In starting the furnace a small number of briquets are fed into the bottom of the furnace through 18, the electrodes are lowered and the current turned on. More briquets are added from time to time, and the electrodes raised until a sufficiently long column is in the furnace. Nitrogen is introduced at 12, when the temperature is 800 to 1000 deg., and the cyanogen compounds and CO formed pass off through 15 to a condenser, where the cyanide is condensed. After a charge is sufficiently treated, it is dumped through the grate bars 7 by means of lever 11. The furnace is thus intermittent.

A continuous furnace is also described which differs from the above in that it has a means at the bottom for continuously removing the treated charge, means for continuous feeding and the resistor zone is limited to the central portion of the furnace. The continuous furnace also has a preheater, while in the intermittent furnace the briquets are preferably preheated during the process of making them (1,174,668, March 7, 1916).

Molten Bath Process for Nitrogen Fixation.—In a previous patent of JOHN E. BUCHER of Coventry, R. I. (No. 1,091,425, March 24, 1914), a process of nitrogen fixation is described in which an iron catalyzer is used in solid form. It was deemed advisable to keep the temperature below the eutectic point of iron and carbon, since carbon was used in the process. When the finely

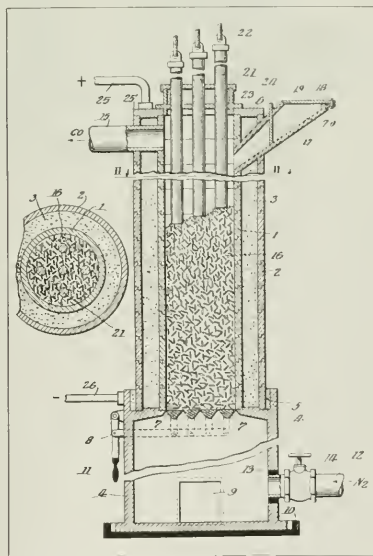


FIG. 10—ELECTRIC FURNACE FOR CYANIDES AND CYANAMIDS

divided iron started to sinter or melt the contact condition were disturbed and the reaction was very much retarded.

In a more recent patent (assigned to Nitrogen Products Company of Providence, R. I.) Bucher states that the objections to the older process have been overcome and that it is possible to use a much higher tempera-

ture. A furnace for carrying out the new process is shown in Fig. 11. A receptacle 1 of cast iron is lined with a prepared lining 2, made up as follows: very hard, compact, magnesia brick is powdered in an iron mortar to pass 20 mesh. To 50 parts of this powder 50 parts of alundum cement and from 2 to 5 parts of borax glass or borax are added. These are mixed and ground in a suitable mill. In the bottom of the furnace, openings 3 are made through which the gaseous products are passed into the molten iron 5. The gaseous reagent consists of nitrogen and an alkali vapor, preferably

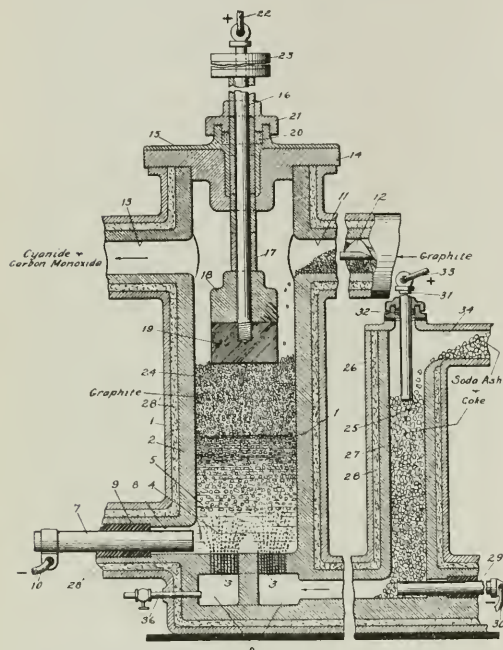


FIG. 11—ELECTRIC FURNACE FOR CYANIDE PRODUCTION

sodium. On top of the layer of molten iron in the furnace is a layer of graphite as designated. This is fed in by the screw conveyor at 12. The lower and upper electrodes are shown at 7 and 18 respectively. The upper electrode is weighted in order to press the graphite down into the molten iron. This is stated to improve the process by keeping the iron saturated with carbon and forcing a better distribution of the gas bubbles.

The cyanide and carbon monoxide formed pass out at 13 to a suitable condenser. If too little carbon is present in the reaction zone, cyanamid will be formed. Sodium vapor may be made from soda ash and coke, as shown at the right of the furnace. These materials are used as a resistor and the sodium vapor passes up at 3 with the nitrogen. These gases are preferably preheated to 800 to 900 deg. C.

If the operation is conducted at a low enough temperature it is possible to use soda ash introduced as a liquid or vapor, or it may be blown into the reaction zone with a current of nitrogen, ammonia, or producer gas. Instead of using iron, ferromanganese may be used, which will permit of a lower furnace temperature. Nickel and cobalt may be added for this purpose also. When iron only is used the temperature is 1500 deg. C. or higher (1,174,944, March 7, 1916).

Nitrogen Fixation Furnace.—A new arrangement of the Birkeland-Eyde nitrogen fixation furnace is the subject of a patent of HARALD BONNEVIE, of Rjukan, Norway (assigned to Norsk Hydro-Elektrisk Kvaestof-faktieselskab). In the ordinary Birkeland furnace the air passes through the furnace in the direction of the arc. In a modified form, air is blown sideways through the flame. The present patent proposes to arrange the magnetic field and air supply so that a steam boiler, with fire tubes, may be placed adjacent the flame in order to cool the gases efficiently after they pass through the flame. Such an arrangement is shown in Fig. 12, which represents a horizontal flame disk furnace. The furnace chamber is shown at A, the electrodes at B and the flame arc at C. The air supply D is placed below the furnace chamber and air is blown through the perforated wall E into the flame arc. The gases pass up through the fire tubes of boiler F into an annular box G connected with outlet tubes. H and K are the magnets connected by iron frame I. The upper magnet is of less strength than the lower so as to give a vaulted shape to the flame.

In order to improve the refrigeration of gases coming from the flame zone by means of the cooling wall on the back side of the flame one may use a current of cooling air or gases to be introduced radially to the plane of the flame arc from the circumference of the flame chamber along the back face of the flame disk and with a slight backward turn in the direction of the gas current. Experiments made with the Birkeland-Eyde flame arcs have shown, in fact, that the same have their maximum amount of energy in their central and outer zones, and this leads to the presumption that here too the reaction of the gases will be most

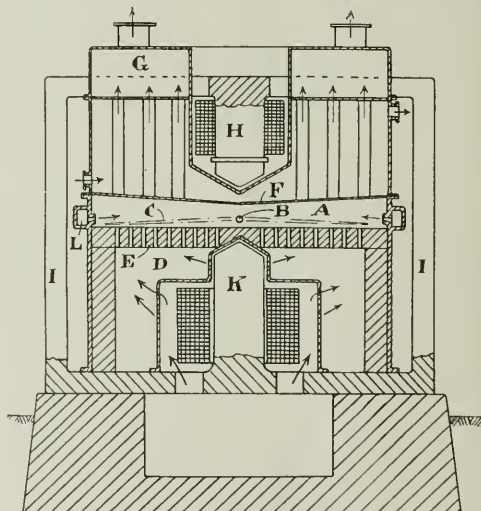


FIG. 12—BIRKELAND-EYDE FURNACE

intense. By introducing an air or gas current directly over this zone one will be enabled to increase in a very efficient way, above the most critical range of the flame field, the cooling effect required to impede the dissociation. On the drawing the inlet duct for this cooling air is marked L. It is remarked, moreover, that the air supply openings should be so distributed in E that the amount of air supplied in any point will correspond approximately to the amount of energy which the arc is capable of rendering at that point; the fire tubes of

the boiler may be distributed accordingly. (1,173,699, Feb. 29, 1916.)

Chemical Engineering

Drying Apparatus.—A drying apparatus designed on the lines of a continuous superposed hearth roaster is patented by GEORGE H. BENJAMIN of New York, N. Y. The apparatus is cylindrical with a central vertical shaft to which are attached a series of superposed disks which rotate with the shaft. An outside casing encloses the disks and shaft. The material to be treated is fed onto the disks and as it is fed it is leveled and moves around toward a hot-air inlet which has dampers so arranged that the air can be admitted to any or all of the disks. The air outlet, the feeder and hot-air inlet are close together on the periphery, the feeder being between the two air ducts, but the incoming warm air goes in an opposite direction away from the material upon entering so that the first air encountered by the material is the air containing the greatest percentage of moisture. As the disk moves, the material is gradually brought into contact with warmer and drier air until it reaches the air inlet. This operation is continued until sufficient moisture has been removed, when a scraper opposite the air inlet is turned down and a certain portion or all of the material (depending on how far down the scrape is turned) is diverted to a delivery duct. The apparatus may be connected to a vacuum pump if desired, and a portion of the air exhausted before reaching the air outlet or auxiliary air may be added at different points by pipes. (1,172,576, Feb. 22, 1916.)

Gas Washer.—A gas washer designed to prevent channelling of the gas through the washer, which reduces the efficiency, is patented by HERMAN A. BRASSERT and CHARLES J. BACON of Chicago, Ill. A vertical sectional view of this apparatus is shown in Fig. 13. The gas inlet is at 11, and the outlet at 12. The arrangement shown at the bottom is to provide a trap, and for the overflow of water.

The gases upon entering the washer first encounter six or eight rows of baffles 19, in the form of wooden strips placed vertically in the manner usually employed. After emerging from these baffles the gases pass through concentric gas passages 20 and 21, formed by superimposed circular perforated trays, 20a and 21a. These trays collect the water from above and cause a shower of water to fall through the gas. This effects a redistribution of the water in case it had been channelled. Leaving the tray sections, the gas passes through another set of baffles 22, the same as those at 19. After passing through the second set of baffles the gases strike inclined baffles as shown, against which sprays of water are played. The velocity of the gas through the lower parallel baffle sections should be between 5 and 15 ft. per second; through the tray sections between 15 and 25 ft., and through the final washing stage between 5 and

15 ft. per second. It is only necessary to dimension the tower and passages so that the proper velocity is attained. (1,172,930, Feb. 22, 1916.)

Iron and Steel

Apparatus for Recovering Sludge from Blast Furnaces.—A process for the recovery of sludge, and its utilization instead of water, in wetting down the charge in a blast furnace is patented by HERMANN A. BRASSERT and WALTHER MATHESIUS, of Chicago, Ill. The gas generated in the blast furnace passes into a dust catcher, where the heavier particles of solid matter are removed. The gas then passes to a gas washer where it is further cleaned of solid particles. These solid particles fall to the lower portion of the gas washer and are discharged through the outlet into a settling tank. The settling tank consists of a series of compartments with cone-shaped bottoms, each compartment having a connection from the bottom to a common pipe communicating with a storage tank. An outlet pipe from the storage tank is located near the skip tub. At the proper time a valve may be opened and a quantity of the sludge discharged into the tub, whereby it is carried to the top of the blast furnace on the skip and dumped into the top of the furnace. It is claimed that by this process it is possible to wet down the furnace burden to better advantage than if water were used, and, at the same time, to save the ore passing off in the gas. (1,171,696, Feb. 15, 1916.)

Dephosphorized Pig-Iron from Electric Furnace.—A process for producing iron practically free from phosphorus from ore containing considerable of this element is described in a patent issued to the late PAUL L. T. HEROULT. The process consists in first making ordinary pig iron in the blast furnace as usual and then transferring it in the molten state to an electric furnace where it is treated with proper slags and regulation of temperature in an iron-oxidizing atmosphere, so as to dephosphorize it to the desired extent.

When the molten pig iron is first introduced into the electric furnace a basic slag, containing as much lime as possible, and containing also some oxide of iron, is applied to the bath, and the current is regulated so as to maintain a low temperature, just sufficient to keep the slag molten and to cause the same to combine with the silicon and phosphorus in the bath, leaving the carbon content of the metal practically unchanged, or only slightly reduced. When the dephosphorization has proceeded to the desired extent, the first slag is removed and a second slag is substituted consisting, for example, of lime and fluorspar with coke dust added. This second slag is very basic and practically free from oxide of iron. The effect is to remove all, or practically all, of the sulphur. Thus the product obtained from a phosphoric ore is a dephosphorized and desulphurized pig iron of the finest quality, which is obtained at an expense considerably less than is involved in the obtaining of a similar pig iron by other processes.

The electric furnace may be of any suitable type, the Héroult arc type being preferred. It may be a tilting furnace or a stationary furnace fed by an intermittent or a continuous flow of the iron from the blast furnace or mixer, or cupola, and tapped to remove the refined iron as desired. The lining of the furnace should be basic. Carbon may be added in the electric furnace if desired, and various other known or suitable additions may be made. (1,172,597, Feb. 22, 1916.)

Aluminium

Process of Producing Alumina.—A process of producing alumina is patented by HEINRICH F. D. SCHWAHN of Belleville, Ill. Aluminous material or ore

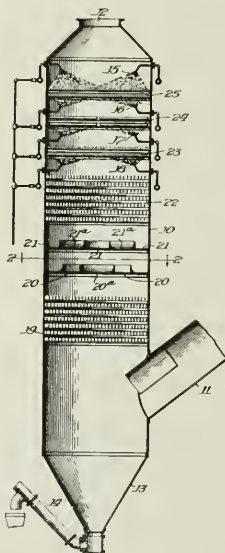


FIG. 13—GAS WASHER

is ground and treated with sulphuric acid and the sulphate of aluminium solution separated and evaporated to dryness in a vacuum pan. The mass is then ground to about 50 mesh and fed into a revolving iron calciner, such as usually used for clinker burning in cement plants. Directly below the sulphate feed is a crude oil burner which supplies the heat. The sulphate falls directly into the flame and is broken up into alumina and sulphur gases. The force of the oil burner and slope of the calciner carries the gases and alumina through the calciner and the alumina receives a coating of carbon which aids in its subsequent reduction to aluminium. The sulphur gases are passed to an acid plant. (1,171,360, Feb. 8, 1916.)

Aluminium-Magnesium Alloys.—In a patent of WALTER N. NAYLOR of Forest Hill, London, and STANLEY P. HUTTON of Beckenham, London, a process of treatment of aluminium is described which is stated to produce a metal of increased strength, which prevents wasting or aging, and which renders the metal non-corrosive in salt water. A certain percentage of magnesium and phosphor tin are added and some phosphorus may be added if required and for certain purposes a percentage of phosphor copper may be added to the mixture to increase the tensile strength. The percentage of magnesium generally exceeds that of the tin and the percentage of magnesium is varied according to the purpose for which the alloy is required. For example, the magnesium is reduced when the metal is to be rolled or drawn. For other purposes, as, for example, dental purposes, a small quantity of metallic sodium may be added.

One alloy, adapted for use in sea-water, is made in the following proportions by weight: $\frac{1}{2}$ lb. aluminium, $\frac{1}{4}$ oz. magnesium, 3 grams phosphor tin, 2 grams phosphorus. This may be varied for a drawing mixture as follows: 4 lb. aluminium, $\frac{1}{2}$ oz. magnesium, 2 grams phosphor tin. For increased tensile strength the alloy may be varied as follows: $\frac{1}{2}$ lb. aluminium, $\frac{1}{4}$ oz. magnesium, $\frac{1}{4}$ oz. phosphate copper, 3 grams phosphor tin. For dental purposes it may be varied as follows:

4 lb. aluminium, $\frac{1}{2}$ oz. magnesium, 1 gram phosphor tin, 2 grams metallic sodium.

Fig. 14 at the left shows the apparatus together with a crucible. A quantity of aluminium is melted in a crucible *a* and to this is added at a temperature of about 600 deg. C a percentage of magnesium and phosphor tin. The magnesium and phosphor tin are incorporated with the aluminium by means of a device in the form of a tube or casing *b* through which the magnesium is made to enter the molten aluminium at the bottom of the crucible, this method being adopted owing to the low melting point and specific gravity of the magnesium. The tube or casing *b* is cylindrical and open at its lower end and it is fitted with a plunger or piston *c* and sliding rod *d* which passes up through the tube and extends for a considerable distance beyond same.

In use the tube *b* is charged with pieces or blocks of magnesium *e*, with pieces of phosphorated tin *f* placed in between. The sliding rod is drawn out as shown to left of the figure for the purpose of charging the tube and a suitable wad of paper or other fabric *g* is placed between the end of the piston and the hole through which the rod slides. The open end of the tube is now blocked with a wad so as to keep it in place. At the required time the tube charged as described is thrust with its open end downward into the molten aluminium. The contained magnesium and phosphor tin are quickly melted out and flow into and mix with the aluminium in the crucible, the weight of the plunger or sliding rod *d* assists in forcing out the contents of the tube as it descends, and the position of the said rod serves to indicate when the metal has been properly melted out and diffused. The molten metal thus mixed may be suitably stirred with a carbon stick or in other suitable manner to insure a thorough incorporation of the magnesium with the aluminium. The upper end of the sliding rod *d* may be fitted with a smaller bell-shaped cavity or cup *h* whereby any further addition of small quantities of phosphorus may be made by wrapping a piece of phosphorus in tin foil, and inserting it in the cup, the cup being then plunged into the molten metal. The small cup *h* may, if required, be made as a separate tool at the end of a rod.

At the right is shown a modified form in which a shallow bell-shaped casing is provided and fitted with a piston *c*, having an extended rod as before described. With this construction a substantially large block of metal may be dealt with as indicated, instead of small pieces as in the other apparatus. A removable cross-bar *j* is provided for keeping the blocks of metal in place until melted. (1,475,655, March 14, 1916.)

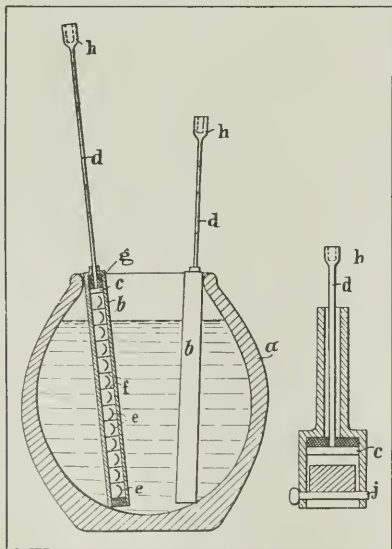


FIG. 14—APPARATUS FOR MAKING ALUMINIUM-MAGNESIUM ALLOYS

The Phosphate Resources of the United States was the subject of a paper presented at the Second Pan-American Congress by Mr. GEORGE R. MANSFIELD. In South Carolina operations began in 1867. Until 1885 this State produced more than 95 per cent of the marketed phosphate of the country. Because of unfavorable conditions the South Carolina rock has been largely superseded by the Florida and Tennessee product. Florida is now the chief producing State, and the rock marketed averages 70 per cent or more tricalcium phosphate. Tennessee ranks second in phosphate production. In Kentucky, Alabama, and Arkansas phosphates occur similar to those of Tennessee. They are not now commercially important. The western field, in Utah, Wyoming, and Montana, contains a great body of rock, averaging 70 per cent or more tricalcium phosphate and a still greater body of lower grade rock. Remoteness from markets, greater cost of mining, and high transportation rates prevent any considerable exploitation now, though some of the rock is used in Pacific Coast States.

A New High-Speed Turbo Blower

The Ingersoll-Rand Company, New York, has added to its turbo compressors and blowers a low-pressure machine to handle volumes from 3000 to 35,000 cu. ft. per minute at from 1 to 2½ lb. These are particularly adapted to such service as foundry cupola blowing, atomizing oil for oil burners, supplying blast to heating and annealing furnaces of various kinds, blowing air for water gas generators, pneumatic conveying and ventilating. They are of the single-stage, double-flow type and are furnished for either electric-motor, steam-turbine or water-wheel drive.

Electric drive is generally employed for the classes of service above mentioned, and in the case of the I-R turbo blower, the high operative speed permits direct coupling to the motor, a first-cost economy. The motor drive maintains constant pressure, while delivering any volume from zero to maximum demand and proportionately varying the electrical horsepower input.

These blowers embody the four bearing construction featured in all turbo machines of this make. The casing is horizontally split for ease in installation and subsequent inspection. The assembled casing is doweled and bolted to a heavy sub-base which ordinarily serves for both blower and driving element. The blower occupies small floor space and its vibrationless operation obviates the necessity for foundation bolting.

The impeller is of the inclosed double-flow type, claimed by the manufacturer to secure the highest efficiency. The wheel is machined from a solid, special steel forging. Vanes and covers are of pressed steel securely riveted. All rivet heads are driven flush and the entire assembly polished. Every care is taken to reduce skin friction. All impellers are overspeeded in a testing machine to insure correct balance, strength and eliminate vibration. Impellers are keyed to a heat treated, forged steel shaft. Labyrinth packing is employed to prevent leakage between impeller and casing. Bearings are ring oiled and both bearings and their housings are horizontally split. The use of flexible couplings between blower and driving unit is standard practice on all I-R turbo blowers. Machines are all of the closed intake type. The intake opening is at the bottom and discharge at the top.

The flow of air from this type of blower is absolutely uniform, avoiding all pulsations, which makes it especially desirable for foundry work. The manufacturer emphasizes the fact that there are no rubbing surfaces

and points out that this precludes the necessity for adjustment to take up wear and minimizes the cost of maintenance. It is to be noted that the only lubrication necessary is that of the bearings, all other parts working without friction.

Tests on Domestic Laboratory Porcelain

When it became a definite certainty that the foreign sources of supply for laboratory porcelain ware would be stopped for perhaps an indefinite period and that chemical and other laboratory work in America would suffer serious inconvenience thereby, Mr. C. D. Fraunfelter, president of the Ohio Pottery Co., set to work on a long series of experiments on bodies and glazes for laboratory porcelain ware with the determination to produce an article that should be the equal of the famous standard ware, the Royal Berlin.

Many formulæ for body and glaze were tried, and conditions of drying, glazing, burning and tempering were carefully studied. Thousands of experimental pieces were made until a line of ware was produced which stood up under all of the tests given below.

The ceramic engineering problems were studied and solved by Mr. Fraunfelter. The chemical laboratory work and the testing of the ware as well as many suggestions as to details of design and adaptability to laboratory practice were contributed by Mr. Robert C. Schroth, Jr., president of the Laboratory Supply Co., Columbus, Ohio, who are selling agents for the new ware.

Every trial run was subjected to the following tests, the results below being the properties exhibited by the series which was adopted for the market. Each sample was taken at room temperature (about 20 deg. C.), plunged without pre-heating into a muffle furnace at 926 deg. C. After four minutes it was removed by means of a pair of steel tongs, not previously heated, and tossed upon a steel plate in a draft. Of eight samples so tested none were cracked or crazed.

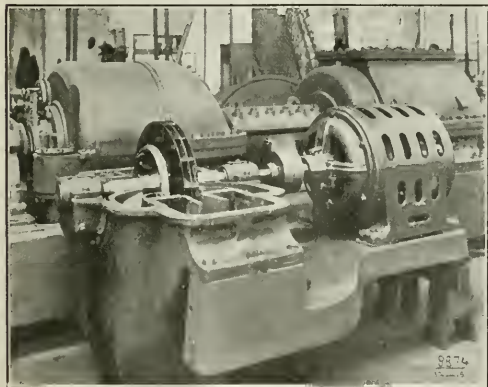
The solubility in 30 per cent sulphuric acid boiling for six hours was found from two tests to be 0.0016 per cent.

The solubility in 25 per cent sodium hydroxide, boiling six hours, was found from two tests to be 1.5 per cent with a uniform and smooth effect on the glaze. Similar tests on two pieces of Royal Berlin ware show a solubility of 1.8 per cent.

The gain in weight from ferric oxide ignition was found from two tests to be 0.001 per cent, with the glaze practically unaffected and no crucibles cracked.

Casseroles and evaporating dishes were run through limestone analysis and showed an average loss in weight of 0.001 per cent with glaze left smooth and clean. They were also run through iron and steel analysis and showed an average gain in weight of 0.002 per cent with glaze left smooth and clean. Photomicrographs were taken of different glazes and showed a practically homogeneous body free from pits and bubbles. Fractures were made and examined microscopically and showed perfectly vitreous, free from any granular structure.

Invar Nickel Steel—Nickel steels with varying percentages of nickel from 1.5 to 95 per cent nickel are used for a wide variety of purposes. The alloys sold under the trade marks Invar, Dilver and Platinite are protected by patents and are manufactured only in France. However, there are a number of companies in this country who make nickel steels of any practical percentage of nickel within the limits already mentioned above.



LOW PRESSURE TYPE TURBO BLOWER WITH UPPER CASING REMOVED SHOWING DOUBLE FLOW ENCLOSED IMPELLER

Welding Sheet Aluminium

A remarkable development of the oxy-acetylene welding process is its application to welding aluminium bodies in the automobile industry. Some details of this process should prove interesting.

In Fig. 1 is shown the back quarterpanels of a Franklin roadster body made by the Walker-Wells Co. of Amesbury, Mass. This consists of a solid piece of sheet aluminium extending from the door opening on one side around both quarters and across the back and could be constructed in no other way except by welding. The forming of the other various sections presented many difficulties which were solved by the welding process. In Fig. 2 is shown an operator welding in the front panels of a Franklin cowl. Many important savings in time and material have been effected by this means. For the special purpose of welding aluminium the Prest-O-Lite Co., Inc., of Indianapolis, has developed a blowpipe which is called the "Baby" welding blowpipe.

In the majority of operations, the edges of the sheets to be welded are turned at right angles to a height from one-and-one-half to two times the thickness of the metal. After applying a flux to cause the metal to flow freely, in a manner described later, these upturned edges are brought together and held with clamp tongs, such as are being used by the operator in Fig. 2. A short section of a few inches is then welded.

This welded section is allowed to cool thoroughly before removing the clamp, otherwise a crack would develop which might follow the subsequent welding, as aluminium when subjected to intense heat is very fragile. The tongs are then moved a few inches along the line of the weld and the metal welded to that point. This is continued until the entire section has been joined.

The part not yet welded is allowed to hang free, or is held by a helper, according to the size and shape of the sheets. Oftentimes the helper assists the welder by manipulating the free ends of the unwelded portion by bringing them into their true relative positions as the clamp is moved along the line of the weld in advance of the welding operator.

Preliminary "tacking" of the joint at regular intervals, with the welding flame, except at the point where the weld is begun, is not considered good practice as it has a tendency to cause a "buckling" of the sheets as the weld progresses which interferes with the progress of the operator and nearly always results in bad workmanship.

The proper use of a fluxing agent is one of the most important points to be watched in sheet aluminium welding. Its improper application nearly always results

in imperfect work. The following information will prove useful to welders engaged on sheet aluminium work.

A special sheet aluminium flux, mixed with water to the consistency of cream, is applied to the line of the weld by means of a stiff brush similar to a painter's "sash tool." After the weld has been completed the flux is washed off either with a scrubbing brush or, as is more commonly the case, with a bunch of waste soaked in cold water, the water being applied freely.

It is necessary to remove all of the remaining flux from the line of the weld and the adjacent metal for the reason that practically all aluminium fluxes contain chlorides and aluminium is very susceptible to the action of chlorine, either in the free state or in combination with other elements. This causes corrosion which may or may not appear until after the body has been painted, when it will cause the paint to peel.

Not all fluxes can be used in a wet form, but in the event that a dry flux is used the same precautions in regard to removing all traces of the flux apply. It is customary to have a pail of water handy so that the scrubbing may be done immediately upon the completion of the weld.

Care should be exercised not to "trap" the flux in the weld, in which case no amount of scrubbing would remove it. By "trapping in the weld" is meant the flowing together of the metal in the joint above and below the flux so that the flux cannot be entirely burned out.

An advantage in using flux in a moist condition is that, when applying the first coat with a piece of cloth, both edges of the metal must be rubbed to a distance of about three-eighths of an inch, which operation effectually removes any oxide from the surface of the metal and also destroys any greasy material which might form a film over the molten metal. After this is done a second coat should be applied sparingly with the stiff brush.

No filling material is used in the welding operation except at such points as a defect may occur, through either the improper handling of the welding flame or lack of a sufficient quantity of flux to allow the metal to flow together freely. In this case, usually a narrow strip cut from the same metal is used as a filler and the operator re-fluxes the line of weld before starting to fill in the defective spot.

After welding, the line of weld is hammered flat under spring power hammers, similar to those used for flat hammer work in all sheet metal industries.

The "Baby" welding blowpipe is used in this class of welding is a new product and is peculiarly adapted to



FIG. 1—BACK QUARTER PANELS OF FRANKLIN ROADSTER, WELDED AT POINTS MARKED "A." TIME, 4 MINUTES

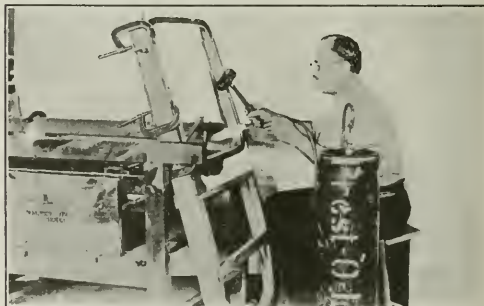


FIG. 2—OPERATOR WELDING IN FRONT PANELS OF FRANKLIN COWL. NOTE METHOD OF HOLDING SHEET IN POSITION FOR THE WELD. THIS ALSO ILLUSTRATES THE COMPLETE OXY-ACETYLENE WELDING OUTFIT

sheet aluminium welding on account of its small size (weighing but a few ounces) and its easy manipulation. With it a workman can weld thin sheets more rapidly than with the heavier type of blowpipe such as is commonly used in large repair work.

Air Meter for Flotation Work

There are very little data available as to the air requirements of flotation cells though this is an important matter, as the total volumes and horsepower involved are very large. In order to meet the demand for a meter to register the cubic feet of free air per minute taken by flotation cells, the New Jersey Meter Co., Plainfield, N. J., has developed a meter, called the flot-om-eter.

A general view of this meter is shown in Fig. 1 and a section is shown in Fig. 2. The principle is the same as that of the tool-om-eter made by the same company for pneumatic tools, *i. e.*, the volume of air flowing under small constant head through multiple orifices of the same shape and size is directly proportional to the number of orifices.



FIG. 1—GENERAL VIEW OF METER

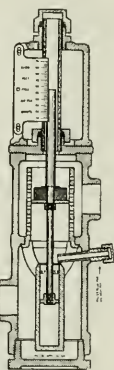


FIG. 2—SECTION OF METER

Referring to Fig. 2, the moving element consists of a weighted piston in the upper or metering cylinder, a small piston in the oil dashpot cylinder and a rod joining the two pistons, and extending upward where it moves freely, without contact, inside the sight glass at the top of the meter. This rod rises and falls with the pistons so that its height in the sight glass corresponds exactly to the position of the piston in the metering cylinder. The scale plate mounted against the outside of the sight glass permits reading the exact height of the top end of the rod.

Air enters at the lower left hand opening into the chamber surrounding the dashpot cylinder and passes through ported openings into the interior of the metering cylinder, the wall of which is drilled with a large number of small accurately reamed holes uniformly spaced (only the holes in the plane of section are shown in the cut). To pass to the outlet chamber the air lifts the piston and exposes some of the holes to the flow.

A small "head," or difference of pressure, is established between the interior of the cylinder and the out-

let chamber; this pressure difference, only a few ounces per square inch, being fixed by the exact weight of the moving element and the area of the piston on which the difference of pressure acts. The moving element rises until the weight is exactly supported by the difference in pressure; the pistons and rod are then floating in static balance in a position corresponding exactly to the volume of air flowing, the number of holes exposed and the height of the top of rod in sight glass. The divisions of the scale plate are calibrated by comparison with a standardized instrument to read correctly.

The flot-om-eter is designed for a normal pressure of 5 lb. per square inch and for use at an altitude of 5000 ft. The capacity under these conditions runs from a minimum of 20 to a maximum of 200 cu. ft. of free air per minute. The company found that the majority of flotation plants were nearer 5000 ft. than sea level, so the meter is standardized to give readings on the basis of free air at the barometric pressure corresponding to that elevation, although the meter can be used at any other elevation arranged for.

From the best information obtainable the maximum requirements for a rougher cell is about 160 ft. and the minimum for a cleaner cell probably seldom less than 40 ft. per minute. The capacity of the meter therefore covers the required range with a margin to spare above the maximum and below the minimum.

The general use of such meters should lead to improvements in the operation of flotation cells, as it would give definite information as to the exact air consumption and enable those in charge to determine the most economical operating conditions as regards air. It would also permit expert supervision or standardization of the operation after the right conditions are found, permitting unskilled men to get the desired results thereafter by merely following fixed instructions as to the rate of air flow.

Second National Exposition of Chemical Industries

The Second National Exposition of Chemical Industries to be held at the Grand Central Palace, New York City, week of Sept. 25, is well under way and, following the success of the first one, it is anticipated that the second exposition will be even more successful.

The Advisory Committee of the Exposition has been enlarged and now includes: Charles H. Herty, chairman; Raymond F. Bacon, L. H. Baekeland, Henry B. Faber, Bernard C. Hesse, A. D. Little, R. P. Perry, William Cooper Procter, E. F. Roeber, George D. Rosen-garten, T. B. Wagner, Utley Wedge, and M. C. Whitaker. The Exposition will again be managed by Charles F. Roth and Adriaan Nagelvoort.

The American Chemical Society has already arranged to hold its annual meeting during the same week of the Exposition, so that its members may avail themselves of the opportunity of reviewing all the exhibits and attending the meetings of the Society. Other societies are also contemplating holding their annual meetings in New York at the time of the Exposition.

The management is now arranging for exhibits on the second floor of the Grand Central Palace, as the main floor has but very few spaces remaining unsold.

Among the roster of exhibits we find the names of representative firms prominent in the world of chemical industries to-day. Notably among these are:

Buffalo Foundry & Machine Co., United Lead Co., J. T. Baker Chemical Co., Benzol Products Co., Thos. A. Edison, Glens Falls Machine Works, Lenz & Naumann, J. F. Devine Co., E. I. DuPont de Nemours Powder Co., Bimex & Amend, The Barrett Company, METALLURGICAL AND CHEMICAL ENGINEERING, The Pfaunder Co., Toch Bros., Merck & Co., Norton Co., Detroit Range Boiler Co., Sharples Specialty Co., Condensate Co. of America, Duriron Cast-

ings Co., Haritan Copper Works, The Dorr Co., Schutte & Koerting, Schaeffer & Budenberg Mfg. Co., Sowers Mfg. Co., Stamford Mfg. Co., Werner & Pfleiderer Co., Abbe Engineering Co., Tolhurst Machine Works, Zaremba Co., Elryia Enameled Products Co., Emil E. Lungwitz, L. O. Koven & Bro., Swenson Evaporator Co., Dow Chemical Co., Hardinge Conical Mill Co., Standard Aniline Products, Inc., Lead Lined Iron Pipe Co., United States Smelting Co., J. L. Mott Iron Works, The Palo Company, Uehling Instrument Co., Ruggies-Coles Engineering Co., Emil Greiner Co., Scientific Materials Co., International Glass Co., Thermal Syndicate, Ltd., Leeds & Northrup Co., Sweetland Filter Press Co., De Laval Separator Co., Valley Iron Works, Thwing Instrument Co., Celluloid Zapon Co., Boston Artificial Leather Co., Sturtevant Mill Co., International Filtration Corp'n, Williams Patent Crusher Co., E. Badger & Sons Co., Fiske Mineral Coal, Monsanto Chemical Works, E. J. Codd Co., The Research Corporation, Great Western Power Co., and Kieselguhr Co. of America, Huff Electrostatic Separator Co., Carborundum Co.

A New Mechanical Stoker

The mechanical stoker has for many years been recognized as one of the power-plant mechanisms that provide a means of real economy. Several of them are so well known that they are as standard as are the boilers themselves.

The Ko-Shovel stoking machine, which is the subject of this article, has been designed with the object of producing a machine of very low cost and very easy of installation. Its application to any existing boiler front is a simple matter. It is installed either directly in the upper portion of the fire-door opening, or immediately above the door in the boiler front. The entering chute and plunger requires but 5 in. in depth, and when installed in the fire-door opening a new door is provided. The installation does not prevent or interfere in any way with firing by hand or in cleaning the fire through the fire doors.

The method of operation is very simple. Coal is fed into a hopper having sufficient capacity to run the boiler for about one hour, the amount fed to the boiler being determined by the speed of the mechanism which may be automatically controlled. From the hopper the coal passes through a crusher, which reduces the larger lumps to a size suitable for firing, the crushed coal dropping into the plunger chamber.

At intervals, which are determined by the speed at which the stoker is operated, the plunger (which is actuated by two heavy springs under tension) ejects the coal which is uniformly distributed over the fire grate by the action of a water-cooled, peculiarly shaped deflector plate over which it passes. It handles successfully any grade of fuel up to 1½-in. bar screenings or down to No. 5 washed or unwashed coal. It is driven by either steam or electric power as desired. About ½ lb. of fuel is fired at each stroke of the plunger, and the total quantity is determined by the speed of the machine. Automatic regulation of boiler pressure can be secured by an automatic valve, controlling the steam entrance to

the driving engine. Automatic regulation for driving the machine by electric motor is also obtained by boiler steam pressure control.

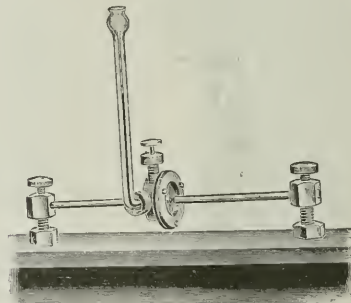
The economy of mechanical stoking is due to several reasons, one of the principal ones being the absence of the necessity for opening the fire door, which is said to cause a loss of at least 15 per cent due to the cooling of gases and furnace walls. This same variation of temperature is also very destructive to both the boiler and its settings, the repairs to which must also be considered in any figures bearing upon efficiency.

One of the principal claims made for the machine is the improved combustion of fuel due to the fact that the charges are small and frequent, and that the fine dust particles of coal are completely and efficiently burned almost instantly and before they reach the grate. In hand-firing this fine coal would most likely find its way into the ash pit unconsumed, or by packing together, as it does when fired in the ordinary way, prevent the passage of the necessary air to sustain proper combustion.

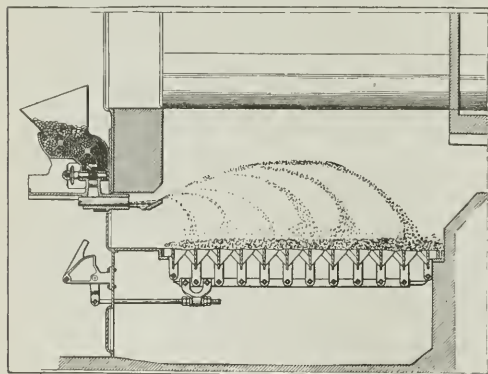
The Ko-Shovel stoking machine is built by the Goetz Company, 403 Monadnock Building, Chicago, Ill.

An Instrument for Determining Actual Strains

An instrument for observing the actual strains and determining actual working stresses in any part of a ship, bridge, crane or other similar structure, or in parts of a slowly reciprocating machine or engine, is being placed on the market by the Palo Company, 90



METER PLACED FOR TESTING



STOKER IN OPERATION

Maiden Lane, New York City. This instrument makes it possible to ascertain the magnitude and character of the strain in any member of such a structure under actual working conditions, or rather the change of strain under operating conditions from moment to moment. In a ship, for instance, the strains set up in any given part of the structure during launching can be noted from moment to moment. When at sea, the strains due to rolling or pitching among waves can be directly determined. Similarly, the effect of a moving load on a bridge, of the weight lifted by a crane, or of any analogous applied loading can be found with accuracy and ease.

In all cases the observations required to measure the nature and amount of the strains and stresses on any or all of the members of a structure may be made on the spot. Since the actual strain between two adjacent points of a piece of solid material is the quantity measured, the elastic modulus assumed for the material is that for an ordinary test specimen, and not a value

modified to include extraneous riveted joints and the like. Consequently no assumptions have to be made such as have hitherto been generally employed when the results obtained in a laboratory have been used to interpret the observed deflections of a structure.

The naval architect or engineer has little difficulty in estimating beforehand the static stresses to be borne by any given design, but in the consideration of wave action and live-load stresses, and particularly of self-imposed stresses due to redundant members or riveted joints, large assumptions have often to be made as to the probable additional stresses that have actually to be met on these accounts. With the strainmeter, tests may be made to bring these assumptions down to quantitative results; the "factor of safety" will become less a "factor of ignorance."

Having in view the use of the instrument on actual structures, simplicity and strength have been the governing features of the design. The instrument is small, light and easily set up in position.

The illustration shows the strainmeter attached to a horizontal plate. It can be used equally well on vertical or inclined axes. The attachment to the plate is made by two $\frac{3}{8}$ -in. studs, case hardened. Where the structural member is so small as to make the drilling and tapping of holes inadvisable, special clamps are supplied. The two studs carry rods which lie parallel to the axis of measurement. One rod carries a chamber communicating with a glass gage tube. This chamber is closed by a flexibly mounted diaphragm, against the center of which the second rod bears. The chamber is filled with colored liquid until the latter stands at a convenient height in the graduated gage tube. The height of the column is adjusted by means of a milled screw working through a stuffing box into the chamber.

After the instrument is set up, any motion between the two points of attachment, due to change in length, will be shown to a greatly enlarged scale by the movement of the liquid in the gage tube. Consequently, any increase or decrease of strain from the static condition when the instrument was fixed is at once read on the gage. When bending takes place this also can be measured. The radius of curvature is seldom small enough to cause any appreciable discrepancy between the arc and the chord on the short base-length of the instrument.

In the standard pattern the multiplying ratio is about 500, the actual figure being given for each instrument. With the usual 8-in. base and on mild steel structures, this enables stresses of 13 tons per square inch to be measured to the nearest one-twentieth of a ton. Where the stress is likely to be greater, or even to exceed the elastic limit, a shorter base, down to 2 in., may be used; thus all ranges of stress are easily covered.

Since the two parts of the instrument are simply in contact, no damage results if the member actually ruptures under test. For use in ordinary commercial testing machines, special studs are supplied, which greatly facilitate adjustment and removal.

The strainmeter is not affected by vibration, and it can be used under difficult conditions. It has recently been used on parts of a vessel near the propellers while at full speed at sea, with entirely satisfactory results. Several instruments are in use to test the strains in decks, bulkheads, steering gear and other parts of important vessels building in this country.

On an 8-in. base of mild steel, the reading is very little affected by temperature. For the usual readings of short duration no account of this factor need be taken. Over long-continued tests, if it is not possible to return to the original conditions, the coefficient may be determined beforehand and note taken of the tempera-

ture changes. Alternatively, a second, or "dummy," chamber may be used, subject to the same temperature but not to the strain, and readings of difference recorded.

The standard instrument measures elongations to the nearest 1/50,000 in. (0.0005 mm.), which is quite close enough for all practical work. For laboratory tests a specially sensitive instrument is made, and a self-recording type can also be supplied.

A Machineable Acid-Proof Iron

One of the most interesting products of the last few years in the field of acid-proof iron which has been commercially successful, and has stood up under many severe tests, is made by the Pacific Foundry Company, San Francisco, Cal. It is known as "corrosion," and is machineable. Some further data on this material should prove interesting.

Corrosion is a high silicon alloy made with especial reference to resistance to corrosion by acid and alkali solutions. From the first stage of development it was found that this alloy could be machined and was capable of being cast in difficult shapes. Many pieces have been made with bars of iron or steel cast within the corrosion section, giving added strength.

The alloy is inclined to be brittle and must be handled carefully. The strength is about one-half that of cast iron. A bar 1 in. by 2 in. by 24 in. tested flat will give about 1200 lb. transverse with deflection about 0.14 to 0.18 of 1 in. The fracture is similar to the fracture of ice, with long flat crystals, not granular. Shrinkage is about that of brass or about 3/16 in. to 1 ft., and in designing, flat surfaces are avoided, all corners rounded and sections of metal kept as even as possible. Very little finish is allowed for finish surfaces, as there is little or no scale, and no deep cuts are required.

Long tests at various temperatures and with various differences in sudden cooling or slow cooling show no appreciable change in crystallization up to melting point of about 1310 deg. C.

A few corrosion tests follow:

98 per cent H ₂ SO ₄	7 days	Loss 0.01	per cent
66 deg. H ₂ SO ₄	7 days	Loss 0.005	per cent
60 deg. H ₂ SO ₄	7 days	Loss 0.005	per cent
46 deg. HNO ₃	7 days	Loss 0.0015	per cent
42 deg. HNO ₃	7 days	Loss 0.0015	per cent
32 deg. HNO ₃	7 days	Loss 0.0015	per cent
1 to 1 HCl.....	17 days	Loss 0.30	per cent
Concentrated.....	17 days	Loss 0.53	per cent
Concentrating Pan H ₂ SO ₄	126 days	0.005	per cent per year
60 deg. H ₂ SO ₄ hot.....	69 days	0.069	per cent per year
45 deg. H ₂ SO ₄ hot.....	125 days	0.171	per cent per year
Hot sludge acid.....	126 days	0.035	per cent per year

Tests on a High-Pressure Pipe and Boiler Covering

The properties and heat insulating value of kieselguhr are well known, but its application to pipe coverings is of more recent origin than some of its more widely known uses. The Armstrong Cork & Insulation Company, Pittsburgh, Pa., has made extensive tests on its "Nonpareil" high-pressure covering which is composed of kieselguhr and asbestos fiber.

A few data explaining the method of conducting the tests, with some of the results, together with a comparison with tests made on 85 per cent magnesia covering and bare pipe should prove interesting.

The plant in which these tests were run comprises a well insulated room, approximately 25 ft. long, 6 ft. wide and 8 ft. high, and a 3-ton refrigerating machine. The testing apparatus proper consists of 15 ft. of 8-in. pipe, blanked off at each end with a cap and set up on wooden supports inside the testing room. There is a

$\frac{1}{2}$ -in. inlet at the bottom of the pipe at one end, and an outlet of the same size at the top of the pipe at the other end, through which hot water flows by gravity. One of the supports is higher than the other so that the pipe slopes upward, preventing air pockets from forming. When covering is being tested, the entire length of the 8-in. pipe is covered with the material under test. In testing the loss from bare pipe, the pipe, needless to say, remains uncovered.

Two calibrated thermometers are set in the pipe 10 ft. apart—21½ ft. from each end—so that the bulb of each thermometer comes about at the center of the pipe. The thermometers are set at that distance from the ends of the pipe, in order that the pipe may be carried on supports outside of the portion under test, namely, the 10 ft. between the two thermometers. The temperature of the room, which is cooled by brine pipes hung along one side, is indicated by two Fahrenheit thermometers, one on either side of, and hanging about on a line with, the 8-in. pipe. A baffle plate, extending from 6 in. above the floor to within 6 in. of the ceiling, is placed in front of the coil to prevent direct radiation and to assure circulation and uniform temperature throughout.

The procedure in making tests is as follows: The refrigerating machine is started, and hot water allowed to flow through the 8-in. pipe. After constant conditions are obtained, the hot water is continually circulated through the pipe and the room held at whatever temperature is decided on for twenty-four to forty-eight hours additional before readings are taken. During the whole of each test the temperature of the testing room is held constant, and the temperature of the ingoing hot water and the amount of flow are kept as nearly uniform as possible. The two thermometers in the pipe and the two room thermometers are read every fifteen minutes through windows in the test room, and the hot water flowing through the pipe caught and weighed with great care. The hot water outlet thermometer, of course, gives a lower reading than the inlet thermometer, this difference being due to the heat which is lost by the hot water in passing through the test area, namely, the 10 ft. of pipe between the two thermometers. All the water is brought into contact with the bulbs of both instruments by means of an ingenious series of baffles in the pipe.

At the expiration of each test, the average difference in temperature between the inlet and outlet thermometers in the pipe, and the average difference in temperature between the hot water and the air in the testing room are determined, and the number of pounds of hot water flowing in twenty-four hours ascertained. If bare pipe is being tested, the surface area of the 10 ft. between the two thermometers must be determined; if covering, the area at the mean circumference.

From these data, the total loss of heat is computed by the following formula:

$$\text{The heat loss in British Thermal Units, per square foot, per degree difference in temperature for twenty-four hours} = \frac{A \times B \times C}{D \times E}$$

where A is the number of degrees loss in temperature of the hot water in passing from one thermometer to the other in the pipe.

B is the number of pounds of hot water flowing through the pipe in twenty-four hours.

C is the specific heat of the hot water, or, in other words, the quantity of heat required to raise one pound of water one degree Fahrenheit, which is one British Thermal Unit.

D is the number of degrees average difference in temperature between the air outside and the water inside, and

E is the area in square feet at the mean circumference of the ten feet of covering between the two thermometers, or the surface area of the ten feet of bare pipe, whichever is under test.

Since, at ordinary steam temperatures, the heat transmission through any insulating material of uniform structure is in inverse proportion to its thickness, the results may be readily reduced to the standard basis, namely, per square foot, at the mean circumference, per 1-in. thickness, per degree difference in temperature

for twenty-four hours. This is accomplished merely by multiplying the transmission through the covering per square foot at the mean circumference, by the thickness of the covering in inches. This unit transmission once determined for any form of covering, the transmission through covering of the same composition of any thickness can be readily calculated. Moreover, by this means the relative efficiency of two different coverings of different thicknesses can be compared on a common basis.

The following tables summarize the results:

NONPAREIL HIGH-PRESSURE COVERING

Date of Test	Transmission per square foot at the mean circumference per 1-in. thickness per degree difference in temperature for 24 hours
March 1, 1913	7.46 B.t.u.
May 16, 1913	7.457 B.t.u.
May 17, 1913	7.58 B.t.u.
May 21, 1913	7.348 B.t.u.
May 22, 1913	7.29 B.t.u.
May 24, 1913	7.39 B.t.u.
May 28, 1913	7.23 B.t.u.
June 4, 1913	7.28 B.t.u.
June 6, 1913	7.29 B.t.u.
June 7, 1913	7.305 B.t.u.
Average, 7.363 B.t.u.	

BRAND NO. 1—85 PER CENT MAGNESIA COVERING

Nov. 22, 1911	7.8 B.t.u.
Nov. 23, 1911	7.7 B.t.u.
Nov. 24, 1911	8.3 B.t.u.
Nov. 25, 1911	8.2 B.t.u.
Nov. 29, 1911	8.1 B.t.u.
Average, 8.02 B.t.u.	

BRAND NO. 2—85 PER CENT MAGNESIA COVERING

Oct. 24, 1911	8.6 B.t.u.
Oct. 26, 1911	8.4 B.t.u.
Oct. 27, 1911	8.42 B.t.u.
Average, 8.473 B.t.u.	

BRAND NO. 3—85 PER CENT MAGNESIA COVERING

Dec. 5, 1911	8.32 B.t.u.
Dec. 6, 1911	8.39 B.t.u.
Dec. 8, 1911	8.33 B.t.u.
Dec. 9, 1911	8.2 B.t.u.
Average, 8.31 B.t.u.	

BRAND NO. 4—85 PER CENT MAGNESIA COVERING

Dec. 12, 1911	8.24 B.t.u.
Dec. 13, 1911	8.2 B.t.u.
Dec. 14, 1911	8.2 B.t.u.
Dec. 15, 1911	8.13 B.t.u.
Dec. 16, 1911	8.1 B.t.u.

Date of Test	
Feb. 11, 1914	8.7 B.t.u.
Feb. 12, 1914	8.35 B.t.u.
Feb. 13, 1914	8.88 B.t.u.
Feb. 13, 1914	9.27 B.t.u.
Average, 8.452 B.t.u.	

BARE PIPE

Date of Test	Transmission per square foot of pipe surface degree difference in temperature for 24 hours
Apr. 3, 1912	52.17 B.t.u.
Apr. 4, 1912	51.4 B.t.u.
Apr. 5, 1912	52.7 B.t.u.
Apr. 6, 1912	52.25 B.t.u.
Average, 51.67 B.t.u.	

A New Industry for Pittsburgh

The Copper Clad Steel Company of Pittsburgh, recently incorporated under the laws of Pennsylvania, has erected a plant at Rankin, Pa., for the purpose of manufacturing copper clad steel products, which will fill a long-felt need in the electrical world. The mills are of the most modern construction and are electrically driven throughout.

After ten years of laboratory and research work, Mr. Jacob M. Roth, president of the company, and Mr. J. W. Reiss, engineer of the company, finally succeeded in discovering a process for the welding of copper with steel or iron so as to produce a perfect weld, without voids, with a commercially uniform conductivity throughout. This result is achieved by a

special treatment of the steel. The steel is placed in a patented mold and this mold is then placed into a specially constructed furnace, designed by the company's engineers. As a result the steel undergoes a special heat treatment, which produces a perfect weld and at the same time improves the steel to such a degree that it makes the tensile strength of steel 30 per cent greater and the elastic limit 60 per cent higher. So absolutely perfect is the "copperweld" that it is impossible to force the two metals apart. The union is entirely without voids. Neither torsions, twists, stretching, strain, stress nor hammering can break the copper covering from the steel core or center. Temperatures less than the fusing point of the material do not change the weld. Not even such extremes of temperature from white heat to a sudden plunge in cold water have any effect on it. "Copperweld" is proof against external corrosion to the same extent that copper is, and the perfect welding of the two metals prevents any moisture entering between them, hence electrolysis can never take place.

"Copperweld" wire has a tensile strength about 60 per cent greater than hard drawn copper of same size and will stand approximately 40 per cent more strain than copper before reaching its elastic limit. This makes possible the use of at least two sizes smaller wire than hard drawn copper for the same purpose, and therefore exposes less surface area to storms, insuring continuity of service, as under the most severe storm of rain, snow and ice, wind and sleet, it never reaches its elastic limit, but hard drawn copper does. This means cheaper initial cost, cheaper to install, and less cost to maintain—all economic factors to be given careful consideration.

"Copperweld" in comparison with copper wire of same gage weighs about 7 per cent less, or in other words, "copperweld" wire of same gage and same weight as hard drawn copper has about 7 per cent greater length.

Personal

Dr. Raymond F. Bacon, director of The Mellon Institute of Industrial Research, Pittsburgh, has been appointed an associate member of the Naval Consulting Board, and will be on the board of directors of the Pennsylvania State organization for industrial preparedness.

Mr. Thomas C. Clarke, formerly president of The Industrial Service Corporation, New York, has opened an office at 111 Broadway as consulting and supervising engineer, specializing in by-product coke ovens.

Mr. George J. Hesch, general manager of The Riverside Acid Works, Warren, Pa., manufacturers of sulphuric and muriatic acids and other chemicals, was recently in New York on business.

Mr. M. R. Hull has been appointed chief engineer of the Arizona Copper Co., Clifton, Ariz. He was formerly on the engineering staff of the Anaconda Copper Co. at Great Falls, Mont.

Mr. E. Humbert, formerly associated with the late Paul Héroult, of aluminium and electric steel fame, is now consulting engineer in electric furnace work in Welland, Ont., Canada.

Mr. M. H. Merriss has resigned his position on the metallurgical staff of the Baltimore plant of the American Smelting & Refining Co. to become superintendent of the electrolytic refinery and silver department at the Raritan refinery of the Anaconda Copper Co. in Perth Amboy, N. J.

Mr. J. J. Nolan, formerly with the Chile Exploration

Co. in their smelting department, is now with the Cerro de Pasco Mining Co. in Peru.

Dr. L. D. Ricketts, president of The American Institute of Mining Engineers, has returned from a trip to South America.

Mr. Daniel M. Rugg, formerly superintendent of the Chattanooga Gas & Coal Products Co., Chattanooga, Tenn., is now with the Gas Machinery Company, Cleveland, Ohio.

Mr. W. N. Sawyer, president and general manager of the Wellman-Seaver-Morgan Co., Cleveland, Ohio, returned recently from a Southern trip, where he had been spending some time recovering from illness.

Mr. G. F. Wood Smith, formerly of the Pennsylvania Tank Car Company and the Pennsylvania Tank Line of Sharon, Pa., is now connected with the Standard Car Construction Company and the Standard Car Equipment Company, with offices in Philadelphia, St. Louis and Wilmington, Del.

Mr. Bradley Stoughton, secretary of The American Institute of Mining Engineers, presented an address on "Melting with Crude Oil in the Cupola" before the Philadelphia Foundrymen's Association on Wednesday, April 5.

Mr. George M. Taylor, general manager of the Portland Gold Mining Co.'s mills at Cripple Creek and Colorado Springs, recently addressed the Chamber of Commerce at Colorado Springs on tungsten.

Mr. E. B. Thornhill, formerly superintendent of the Buffalo mill, Cobalt, Ont., is now with the Metals Recovery Co. of Cobalt, who are making extensive experiments with the flotation process.

Mr. Frank Wilson, manager of the du Pont Powder Co.'s plant between St. Louis and Belleville, has been placed in charge of a larger plant in the East.

Industrial Notes

Aluminium Production in Norway.—A large plant for the production of aluminium is contemplated at Höyanfjord, Norway, where hydroelectric power is available to the extent of about 60,000 hp. It is proposed to develop 20,000 hp. at once to furnish power for the production of 4000 tons of aluminium per year.

Electric Smelting in Newfoundland.—The Hydro Electric Smelting Company, Ltd., has recently installed an electric copper smelter at St. Johns, New Foundland, according to *Commerce Reports*. Tests have been made on ore from the Little Bay copper mines with satisfactory results.

The American Smelting and Refining Co. at its recent annual meeting re-elected its directors. During the year the following were elected directors to fill vacancies: F. H. Brownell, W. M. Drury, Charles Earl, L. G. Eakins, H. A. Guess, C. A. H. de Saulles and H. R. Wagner.

Production of Spelter in 1915.—In a report recently issued by the U. S. Geological Survey, of which C. E. Siebenthal is the author, the production of primary spelter in the United States in 1915 is estimated to be 489,519 tons of 2000 lb. This is an increase of 136,470 tons, or 39 per cent, over the 1914 production. The value of the primary spelter in 1915 presents a striking contrast to the value of 1914, the former being \$121,401,000, which is 237 per cent greater than in 1914.

Canadian Coke Plant.—The construction of a 60-oven by-product coke plant to cost \$2,000,000 is contemplated by M. S. Byrnes and associates of the United Gas & Fuel Co., Hamilton, Ontario.

Potash.—It was recently announced that the \$250,000 kelp plant of the American Products Company, Long Beach, Cal., has been completed and is in successful operation.

The Tungsten Metals Corporation has recently been formed with a capital of \$550,000. The construction of a tungsten mill in Boulder Canyon, Col., will be started about May 1. The corporation has taken over the properties of the Tungsten Metals Co. and the Ferberite Co.

The Carcolite Chemical Company's plant at Copper Hill, Tenn., which was recently destroyed by fire, is to be rebuilt. The plant was controlled by the Tennessee Copper Co.

The American Steel & Wire Co. has started a by-product coke plant at Cleveland to cost about \$6,000,000. The development of by-product coking is reaching larger proportions than is generally realized.

Messrs. Lenz & Naumann, Inc., announce the removal of their offices, showrooms and warehouses to more convenient and commodious premises situated at 9-11 East Sixteenth Street, New York.

The Nevada Section of the American Institute of Mining Engineers will be installed at Reno, Nev., on May 18.

The Chemists' Club, New York, will hold its annual meeting for the election of officers and the transaction of other business on Wednesday, May 3, at 8 p. m.

Progress of Electric Steel Furnace.—The Rennerfelt furnace, the latest of successful European steel furnaces to appear in the field in America, is making rapid progress in this country. Messrs. Hamilton & Hansell, 17 Battery Place, New York, announce the sale of Rennerfelt furnaces as follows: one $\frac{3}{4}$ -ton furnace for castings for the Skagit Steel & Iron Works, Sedro-Woolley, Wash.; one 3-ton furnace for castings and ingots for the American Foundry & Machine Co., Salt Lake City, Utah; two 8-ton furnaces for ingots for the Charleston Steel Co., Charleston, W. Va. Besides these, orders for the following have been placed abroad: one $1\frac{1}{4}$ -ton furnace for castings for the A. B. Svenska Järnvägsverkstäderna, Linköping, Sweden; two $\frac{3}{4}$ -ton furnaces for castings, Stchetinine, Petrograd, Russia; one $1\frac{1}{4}$ -ton furnace for tool steel for Larsbo-Norn A. B., Vikmanshyttan, Sweden; one $1\frac{1}{3}$ -ton furnace for tool steel for Naes Järnverk, Tvedestrand, Norway; one $\frac{3}{4}$ -ton furnace for tool steel for Hulfs Bruk, Sweden; one 3-ton furnace for steel castings and special steels for William Beardmore & Co., Ltd., Forge, Scotland; one $1\frac{1}{3}$ -ton furnace for ferromanganese for F. H. Lloyd & Co., Ltd., James Bridge, Steel Works, near Wednesbury, England. There are now in the whole fifty-four Rennerfelt furnaces contracted for or in operation, of which twenty-one are building.

Messrs. Hamilton & Hansell, 17 Battery Place, New York City, announce the opening of a branch office in Stockholm, which will be in charge of Mr. N. V. Hansell, member of the firm.

Electrotyping Baths.—A bulletin has been issued by the Bureau of Standards (Scientific Paper No. 275), entitled "Relation Between Composition and Density of Aqueous Solutions of Copper Sulphate and Sulphuric Acid." In connection with a study of copper electrotyping baths which usually contain only copper sulphate and sulphuric acid, it was found desirable to devise a simple method for determining their composition. Since the composition of such a solution is fixed, if the acidity and density at a given temperature are known, all that is required to determine the content of copper sulphate is a table showing the densities of solutions of known composition. The densities of such

solutions varying in concentration from 0 to 20 per cent each of copper sulphate and sulphuric acid, were determined at 25 deg. and 40 deg. C., and were found to be constituents and almost independent of their proportion.

Production of Briquets in United States.—European countries have developed the manufacture of fuel briquets to large proportions, while the industry is still in its infancy in this country. The United States Geological Survey states that it will probably be many years before the interest in this class of products reaches a high mark here, but that it deserves far more attention than it is receiving. More than \$1,000,000 worth of briquets were made out of waste coal dust in 1915, the exact production being 221,537 short tons, valued at \$1,035,716. This was the largest output of fuel briquets in the United States for any year with the exception of 1914.

New Chemical Companies Get Japanese Subsidies.—Japan's offer of subsidies for the manufacture of dyes and chemicals has resulted in the formation of three companies in addition to the dyestuff concern recently formed, according to Commerce Reports. The Hongkong *Daily Press* quotes the British commercial attaché as giving the details of their formation. One company, engaged in the manufacture of glycerin, with a capital of 3,000,000 yen (\$1,494,000), intends to take over the business of an oil company at Osaka. The second company, manufacturing medicinal and chemical products, intends to specialize in the manufacture of formalin and its derivatives and in other carbon compounds. This company will have a capital of 500,000 yen (\$249,000) and will acquire the formalin works of an existing Japanese concern engaged in the production of acetic acid. The third company produces medicinal compounds and will have a capital of 1,000,000 yen (\$498,000). The promoters of such subsidized companies are required in the case of chemicals to apply to the Minister of Agriculture and Commerce for permission, and in the case of drugs to the Minister for Home Affairs. When part of the capital is paid up, the first general meeting of the shareholders completed, and the new company registered in the courts, the promoters are entitled to ask for a subsidy. This is to be available for not more than ten years from the date of the enforcement of the law. The amount to be paid by the Government is to be such as to make the dividends the company pays in each business year reach a rate of 8 per cent on the paid-up shares.

Standard Density and Volumetric Tables.—A bulletin has been issued by the Bureau of Standards (Circular No. 19), entitled "Standard Density and Volumetric Tables." In this circular are presented density and volumetric tables for certain substances much used in the arts and sciences, for example, water, ethyl alcohol, methyl alcohol, sulphuric acid, and cane sugar solutions. The circular also contains tables of data useful in certain physical operations, for example, in the calibration of hydrometers and volumetric apparatus.

The Utah Section of the American Institute of Mining Engineers held its semi-annual meeting on March 7. Visits were made to the Utah Copper Company and the Garfield Smelter in the afternoon, and in the evening there was a dinner at the Alta Club, followed by a paper on "Preparation of Powdered Coal for Reverberatory Smelting at Garfield" by R. F. Barker.

Electrolytic Zinc.—A plant will be erected at Drammen, Norway, by the Norwegian Zinc Electro-Metal Company. The Sturbelle process will be used and it is expected that the plant will be in operation sometime next fall.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Aqueous Bath Apparatus

87,442, March 2, 1869, George J. Sturdy and Solomon W. Young of Providence, Rhode Island.

Relates to cleaning small metal articles prior to their being electroplated. The articles are placed in a tumbling barrel containing a solution of potassium cyanid, or an equivalent alkaline solution, and agitated therein until the oxid or other coating is removed. The articles are then ready to receive the electrodeposit.

213,319, March 18, 1879, Aaron B. Brown and Wendell P. Brown of Worcester, Mass.

Relates to cleaning metal prior to electroplating, and consists in treating the metal with a solution of alkaline phosphates, such as phosphate of potash. The metal is cleaned, and does not retain a film of corroding liquid which subsequently injures the deposit.

472,691, April 12, 1892, George H. Benjamin of New York, N. Y.

Relates to cleaning sheet iron plates prior to tinning, by connecting them as the cathode of an electrolytic cell containing an electrolyte of sulfate of sodium or of sulfuric acid in water. The hydrogen set free at the surface of the plates serves to reduce the oxids upon their surfaces, and also to decompose any grease that may be present. If much grease is present, they may first be immersed in a solution of chlorid of sodium, sulfate of sodium, or other neutral salt and charged for about fifteen minutes, and then treated in dilute sulfuric acid for from fifteen minutes to about forty-five minutes, the latter treatment loosening the oxid coating.

490,816, Jan. 31, 1893, Christopher J. Theuerner of Newark, N. J.

Relates to a method of cleaning silver, and freeing it from a coating of oxid which it acquires after annealing. The silver is connected as anode in an electrolyte consisting of 1 lb. of cyanid of potassium, 2 lb. of yellow prussiate of potash, and 2 gal. of water. Lead cathodes are used. The oxid is removed and the article then given the desired finish.

532,394, Jan. 8, 1895, William Stepney Rawson of London, England.

Relates to a process of and apparatus for pickling iron and steel articles, such as sheets of metal. For black pickling, a plurality of sheets are placed parallel vertically in an electrolyte, and spaced apart, the outer plates only being connected as anode and cathode, the intermediate plates acting as secondary electrodes. The direction of current is reversed automatically about four times per minute, or less frequently with large size plates. After about ten minutes the scale is loosened from the surface and finally drops off. An electrolyte containing 6 per cent of 1.140 specific gravity hydrochloric acid or 3 per cent of 1.750 specific gravity sulfuric acid is used. The temperature should be about 70 deg. to 90 deg. Fahr., or higher with weak acid. For white pickling, each sheet is held in contact with a plate of carbon by a frame, the outer carbon being made the anode, and the sheet of metal at the other end made the cathode. After a short time, the current is interrupted, and it is found that the coupled carbon and iron sheets have become charged, that is, they are in the condition of a storage battery, and on short-circuiting

through a suitable resistance, the local current pickles the other side of the sheet of iron; if desired the local current may be increased by an external current. In both black and white pickling, the current may be supplied to the end of the cell through permanent carbon electrodes. For pickling some articles, the sheet iron should be connected to the negative about three times as long as to the positive. The apparatus consists of a clock-work device which periodically closes and reverses an electric circuit which in turn operates an electromagnetic switch, the latter reversing and closing the circuit through the pickling cell.

568,412, Sept. 29, 1896, Alexander Sydney Ramage of Chicago, Ill., assignor of two-thirds to Peck & Roberts and V. P. Sherwin, of same place.

Relates to pickling iron sheets and other articles, and uses as electrolyte a solution of iron and hydrochloric acid, containing about one-quarter of 1 per cent of free acid, and maintained at about 100 deg. Fahr. The article to be pickled is connected as anode, a sheet of iron being used as cathode. The voltage at the pickling cell should be between two and three volts.

570,956, Nov. 10, 1896, Alexander S. Ramage of Cleveland, Ohio, assignor to Joseph C. Gilchrist, of same place.

Relates to a solution to be used in the electrolytic pickling of iron. The solution consists of 278 lb. of sulfate of iron (copperas), 142 lb. of salt cake (sulfate of soda, dry) and 132 lb. of sulfate of ammonia. This solution is diluted with water to make a solution 20 per cent strong more or less. The iron to be pickled is immersed in it, and connected as anode, a voltage of from two to four volts being used.

665,864, Jan. 15, 1901, John Louis Bach of Buffalo, N. Y.

Relates to a composition for cleaning metals, the composition consisting of 1 oz. potassium carbonate, $\frac{1}{2}$ oz. potassium cyanid, $\frac{1}{2}$ oz. sodium carbonate, $\frac{1}{10}$ oz. sodium chlorid, and 1 gal. water. The solution should be used boiling, and the article to be cleaned connected to the positive terminal of an electric current. A formation of gas takes place, which frees the article from all greases or other impurities, and renders it chemically clean.

693,918, Feb. 25, 1902, Carl Steinweg of Lüdenschied, Germany.

Relates to forming bodies by electrodeposition, and consists in cutting grooves upon the surface of a metal base cathode and electrodepositing metal over the form and in the grooves. After completion, the deposit is readily torn along the grooves, permitting the deposit to be removed in sections. With cylindrical objects, the groove may be in the form of a helical cut.

704,400, July 8, 1902, Julius Taluau and Henry W. Scattergood of Philadelphia, Pa.

Relates to a method of framing glass suitable for making stained glass windows, etc., and refers to a prior application filed in 1895, serial number 572,318, on which this is an improvement. A wood support is coated with wax or other adhesive, and the glass pieces properly located and spaced upon the wax, to which they are secured. Plumbago is then applied to the spaces and edges of the glass to receive a deposit, and iron or other metal filings may also be placed in the spaces to help fill them. The deposit is then completed, allowing the upper part to overlap slightly the edges of the glass. If desired, the spaces may be partly filled with solder, Portland cement, or other material. After completion of the deposit on one side, the glass window may be removed from the wax surface, and the deposit completed on the other side to secure the pieces of glass firmly in place.

Book Review

The Metallography of Steel and Cast Iron. By Henry Marion Howe, LL.D., Sc.D., Professor Emeritus of Metallurgy in Columbia University. Quarto, 641 pages, profusely illustrated. With 45 plates of microphotographs. Price, \$10. New York: McGraw-Hill Book Company.

"To Henri Le Chatelier, member of the Institute of France, philosopher, teacher, leader, as a token of affection and esteem this work is dedicated."

The choice of a reviewer for such a work as this is a task which forces the editor upon whom it falls to choose one of the horns of a dilemma: either he must select one of the very limited circle of experts on the subject of which the book treats who of necessity would judge it according to its agreement with or divergence from his own hard-won opinions, or he must intrust the task to a man of the operating type. The latter course furnishes a vastly wider field for choice, but only among men with an almost proportionately slighter knowledge of the subject; nevertheless the editor sometimes chooses this course in the hope that the practical man will obtain enough of the spirit of the work to describe it to the larger field of readers who speak and understand his language.

The reviewer in this case approaches his task well aware of his inadequacy for it. Moreover, a review to be useful must be timely, and this necessity limits the time available for study of the book to weeks, while months or years would be required for adequate comprehension, so that only a cursory examination is possible in this case.

The quotation from Browning on the title page and that from Tyndall in the preface give the spirit of Professor Howe's work better than any words of mine can do:

"A hand conducts me through the cloud round low to where I stand,

Firm on its base—know cause who before knew effect."
(Browning.)

"Right or wrong, a thoughtfully uttered theory has a dynamic power which operates against intellectual stagnation, and even by provoking opposition is eventually of service in the cause of truth." (Tyndall.)

The title of the work seems to the reviewer to do it less than justice for two reasons: First, because "metallography" has come to have in the subconscious mind of the practical metallurgist a connotation of narrowness and ineffectiveness, it has been used a trifle too freely by those who felt the need of breaking into print without having anything in particular to say. Second, because the second and larger half of the book deals with the ultimate structure of steel from all points of view, but especially those of the shapes of the crystals and of the phenomena materials display when tested beyond the elastic limit. The evidence is largely microscopic, it is true, but it is also much broader than the word metallography would imply. As one of a series of several works on iron and steel, the title will probably seem appropriate enough, but for this volume alone it scarcely seems adequate.

The book as a whole can best be comprehended in the light of the preface. It is a deliberate attempt to set forward the boundaries of our knowledge, not with the idea of immediate usefulness to steel manufacture to-day but in the hope that the studious practitioner of the future may apply the laws here so painstakingly sought in order to improve the steel of the future, to the end that less of it may be required and our resources thereby conserved.

To the immense labor involved in this attempt, Pro-

fessor Howe has brought the fruits of a quarter of a century spent in the collection of data, both in the study of the work of others and in laboratory researches of his own; the ability to think in terms of a complex and difficult subject, which can only be acquired by years of application, and a power of analysis which in metallurgical matters has probably never been exceeded.

In setting forth the results obtained, the author has again displayed that ability to express the most complex thoughts in the simplest language, which is the admiration and despair of most other technical writers.

The first half of the book treats of the constitution and microstructure of steel and cast iron in relation to the formation and nature of their different components, and explains the graphic presentation of these phenomena by means of the iron-carbon diagram.

This portion of the book closes with a chapter in the phase rule, which begins with a warning to the reader of the difficulty of the subject and of some of the purposes for which the phase rule must *not* be used, then declares that it is a useful tool for those who understand it, and proceeds to explain its working. The close of the chapter consists not of explanations of the phenomena of the iron-carbon alloys by means of the phase rule, but of explanations of the phase rule by means of the phenomena of the iron-carbon alloys. While the reviewer does not doubt that the phase rule is a convenient guide of wide application for intellectual giants like Willard Gibbs, who invented it, this seems to him to prove that to attempt to explain the iron-carbon diagram to the ordinary practical or technical man by means of the phase rule is simply giving him two difficult subjects to master instead of one.

The last half of the book gives in detail a vast number of phenomena of most of which the average practical steel man is entirely ignorant. It begins with the nature of the various crystals formed by the different micro constituents, the nature and effect of "twinning," the structure developed by the ejection of surplus material into the grain boundaries, etc. Then follows a description of the effects of deformation, the origin of "slip bands," "Neumann lines," "Widmanstätten structure," and an analysis of the intra crystalline, one might almost say the molecular, forces which produce or may produce them.

This portion of the work might fairly be said to begin where practical metallurgy leaves off, and its value to the steel maker of to-day is slight, but its practical importance is not to be despised on that account, for if we look back only twenty years we realize that the microstructure of steel was virtually unknown at that time, while to-day the production and qualities of steel parts in hundreds of plants are controlled by this means.

In the light of this and thousands of similar cases in which the "useless scientific theories" of one generation have become the every-day tools of the next, we may expect that in another quarter century progressive steel men will be shaping their course by the laws which are the object of Professor Howe's patient and penetrating research. That his labors will have to wait the coming of that generation for their full utilization and appreciation is the misfortune of the pioneer. I quote from Kipling's "Explorer":

"Have I named one single river?

Have I claimed a single acre?

Have I kept a single nugget? (barring samples)

No, not I.

God took care to hide that country till He judged His people ready,

Then he chose me for His Whisper, and I've found it and it's yours."

J. E. J., JR.

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Flotation

The symposium on page 569 of this issue on the effect of flotation on cyanidation, the report on page 572 of the joint Mining Engineers and Electrochemical Society meeting in New York on the "how" and "why" of flotation, and the questionnaire on page 562 on theoretical and practical phases of flotation illustrate the rapid progress, which flotation is now making. To formulate a problem correctly is half the solution.

Academic Millinery

In a late number of *The Scientific Monthly* Messrs. C. G. and C. B. MacArthur of Urbana, Ill., have a great deal to say about "The Menace of Academic Distinctions." It worries them. They have seen heads under mortar boards congregating on the campus and appearing to think themselves better and wiser and more to be respected than the other fellows. The June processions of The Intellectuals in sombre caps and gowns and flamboyant hoods seem foolish and undesirable to them. The lowering of scholarship from its great task of promoting human advancement in knowledge and understanding down to so vain a show is, in the minds of these authors, not only undemocratic but poisonous in its effects. No less of an authority than William James is quoted to show the evils of "The Ph.D. Octopus." Another writer is called upon to remind us that "a dozen mortar boards on the campus are more of a menace to democracy than a million dollar endowment from a trust magnate," and the Phi Beta Kappa and Sigma Psi societies are indicated as distinctions without genuine merit, displaying no more real worth than the flaming necktie and the flowery waistcoat of the newly rich.

The protestants against the shortcomings of the universities and the emptiness of their degrees are having their day in court. We hear of them time and again. The learned counsel for the prosecution are enjoying all the usual privileges of "examination with a view to prove defective character." Now, all is fair in love and war and in a court room with an easy judge; but where we think the prosecution errs is in bringing in poor old democracy every time. Democracy is a shibboleth, it is a gospel, and we are in favor of it without knowing exactly what it is. The late John Hay told what he wished it were and we feel that way too, but all the time we are shouting in favor of democracy we are also wishing with all our hearts for system and order and for more character, more unselfishness and more intelligence among those who constitute the people under it. Slowly but surely it is being borne in upon us that democracy fails when public opinion and public conscience deteriorate, and that when democracy fails anarchy rises in its stead. Democracy is subject to a reversible reaction

and goes over into anarchy as public enlightenment and public conscience decrease, returning again to good government, stability and general order as these increase. This is a law, and there is no getting around it. The only way to avoid the rule is to give up democracy and to employ a benevolent tyrant.

Now, since democracy must have for its mere existence the advantage of enlightenment, there is as much hazard in the destructive criticism of universities on the ground that they are undemocratic and perverse of the general welfare as there is in all the processions of the intellectuals and the unhappy picture of their total wives engaged in a snubbing contest. Destructive criticism "is in the air; it is in every stratum of society," as the metaphorist said. For instance, the beneficent anarchy desired by the I. W. W. is all right to talk about, but we know very well that the end of such propaganda is anarchy and not civilization or order. We know very well that those who follow the agitators have, many of them, serious grievances and that they do not get a chance to participate in the pleasant and agreeable things of life. They say that they are entitled to live under better circumstances, and that is right too. But we know also that they and all the rest of us have not, collectively, intelligence and character enough to establish a better order of things and that, much as we may sympathize with them, their unconscious goal is anarchy, disorder, strife and poverty.

The weakness of democracy is anarchy, and it is time that detractors of university methods and work be held to strict account and required to give for every destructive proposal, a corresponding constructive one.

Degrees are given for what is considered to be the attainment of proficiency. The occasional exchange of honorary degrees for endowments is not of sufficient frequency to count. Scholarship has always suffered from the cackle of mouths with small men about them. Let us endure it as our fathers before us have done. But the method of determining proficiency is very defective, and it has always been so because it does not distinguish the men of constructive power from the often foolish memorizers. Instead of making an attack upon the only rewards that universities have to bestow—and our passion for reward is too great to give them up—it would be far better if the detractors were to set themselves to work to devise a better method of selecting candidates, or to provide a qualification of degrees, as of, respectively, constructive and mnemonic honors. Scorn of university degrees will not lessen them; it will only cheapen them until they are so largely bestowed upon the unworthy that men of attainment will select other methods of separating themselves from the noisy crowd which sounds and smells more like anarchy than democracy. If we destroy the value of degrees it may drive the memorizers out of the new orders of the *Cognoscenti*, but it will not drive men of attainment into the crowd. The reason for this is that men of attainment do not like to talk in the language of scare-heads. The crowd to-day wants little else. Why not strive to pull the crowd up rather than to pull the teachers down?

The fact is that most men who have studied in Science

or The Humanities and have not degrees, would like very much to have them. The Messrs. MacArthur say that "business men manage without titles," but that is because they lack them. They chortle with glee when they get them. The oft published Review of the Stock Market by Henry Clews, LL.D., is too frequently received by those recorded in the advertising list as "Investors" to have passed without notice. Sir Robert Burnett's London Dry Gin is emblazoned on the placards of too many street cars to have escaped observation. Sir Robert may have been gathered unto his fathers long ago, but had he received an honorary doctorate we are disposed to believe that that, too, would have decorated his many bottles of gin.

Engineers who desire to get to work without delay may not remain at the universities long enough to take a doctor's degree, but it does not seem either to injure or to shame those that do receive it. The occasional doctors that one meets with among civil, mechanical or electrical engineers do not seem to have lost merit or gained unwholesome vanity because of their titles. As for the members of the Chemists' Club, they seem to be mostly doctors, and we have yet to learn that they have lost their precious gift of democracy.

The Immortals do not need degrees. We do not think of the late Dr. Napoleon Bonaparte in connection with his university distinction, nor do we refer to them in speaking of Charles Darwin. On the other hand, we do say Professor Huxley, Professor Tyndall and Professor Haeckel without belittling them. The title indicates that they have figured as teachers.

We want titles, most of us; and we like them. We are no judges of our own worthiness to receive them because Nature has implanted in every one of us the belief that he is, in one way or another, exceptional. And because of our exceptional qualities, we like to be distinguished. We like to be known as leaders, whether as Bim the Button Man, or the Great Commoner, or the Master of Balliol. We differ in quality but not in desire.

We have in mind a chemist who took his bachelor's degree and then went to work. He worked hard and well and he was a man of remarkable natural endowments. He kept the general principles of chemistry alive in his mind and his professional attainments were far and away beyond those of a majority of men who hold doctors' degrees. He did not like snobs. Certain doctors of philosophy, who knew far less than he, put on airs and frills, and they annoyed him. So he undertook to prove that a good chemist could be as unlike them as possible. His language became vulgar, corrupt and obscene, he offended men of more gracious habit of life—and he went to pieces. These are the two extremes of evil that we face when we quarrel about university degrees: snobbery on the one hand and cultural degeneration on the other. If we only had more sense we might strike a happy medium, and the reason why we do not strike a happy medium is because we have not more sense.

Science above all other studies needs to be set forth with all the art available. A little academic millinery will do it no harm. A doctor's degree indicates a cer-

tain measure of scholarly attainment. This we need. Instead of decrying scholastic degrees we should urge as many students of science as can spare the time, to avail themselves of these great privileges of the universities.

The Domestic Demand for Steel

Despite the fact that the steel mills that produce the great bulk of the steel in the United States are highly specialized they are able to meet a consumptive demand that is distributed in quite abnormal manner among the different steel mill products. This ability to meet a demand of quite unusual analysis is due in part to the fact that steel-finishing capacity is in excess of steel-making capacity, but is due largely to the efficiency by which changed conditions have been met. The steel demand of 1906, for instance, analyzed 22.8 per cent rails, while the demand of to-day analyzes about 8 per cent rails, taking the year as a whole, and much less than 8 per cent during the winter months. The demand for large steel rounds is exceptionally heavy, due to the war, and the condition has been met by equipping many rail mills to roll these large rounds.

The export demand for steel is much more exceptional in its character than in its volume. While the fact is not realized in all quarters, the export demand for steel is not much greater than before the war, by comparison either with the total exports of merchandise or with the production of steel. Thus in 1912 the value of all iron and steel exports, covering the regular tonnage products as well as machinery, hardware, cutlery, etc., amounted to \$289,128,420, and this constituted 12.2 per cent of the total exports of merchandise. In 1913 the iron and steel exports of \$293,934,160 constituted 12 per cent of the total exports. In the eight months ended last February the value of iron and steel exports was \$355,120,855, and this was 14 per cent of the total exports in that period, an increase of only 15 per cent in the proportion. Comparison of iron and steel exports with the total production can be made only by comparing tonnage exported with tonnage produced. In 1912 the weight of all iron and steel exported that was returned by weight was 2,948,466 gross tons, and this tonnage was equal to 9.4 per cent of the weight of steel ingots and castings produced. As the production of steel ingots and castings may be estimated at a rate of fully 42,000,000 tons, the same proportion would suggest exports of iron and steel at the rate of 330,000 tons a month. The exports in the eight months ended February averaged 370,000 tons a month, or 12 per cent more than the prescribed rate, and as exports in the two closing months of the eight-month periods were less than in the first two months it may be assumed that the rate of export has not increased since February.

The analysis of the exports, however, has greatly changed on account of the war. There are exceptionally heavy exports of billets, large steel rounds and

wire products, while the exports of tubular goods, structural steel and some minor products are in exceptionally light proportions. Much attention has been directed to the extremely heavy exports of metal-working machinery for more than a twelve-month, but the exports of certain other classes of machinery, agricultural implements in particular, have been exceptionally light.

The exports of steel in rolled form, as well as the steel consumed in the manufacture of machinery, etc., that is exported, comprise but a slightly larger proportion of the total production of steel in the United States than formerly. As production is far in excess of any rate obtaining in the past, the total tonnage demand of strictly domestic character is far in excess of previous records, and yet the demand for certain classes of finished steel is abnormally light both in proportion to the total production, and absolutely, as to the tonnage involved. Rails, galvanized sheets and structural steel for ordinary building consumption are examples. By some fortunate coincidences demand in certain other directions has fit with these decreases. The demand for large steel rounds, as already mentioned, fits nicely with the small demand for rails. An exceptionally heavy demand for black sheets fits with the decreased demand for galvanized, and an unusual amount of railway structural work fits well with the relatively light demand for structural steel for other purposes.

Market prices for various steel commodities, however, show that the adjustments to a peculiar analysis of demand are not complete, or are brought about only by the payment of what may be denominated a premium. For instance, a price of approximately three cents a pound obtains for far-forward delivery of plates, blue-annealed sheets, 10 gage, and black sheets, 28 gage, when, of course, blue-annealed sheets should command several dollars a ton, and 28-gage black sheets about \$15 a ton more than plates. The vagary is positively amusing, however, when prices for prompt shipment are compared, since for prompt shipment from mill 4c. has lately been paid for plates, 3.50c. for blue-annealed sheets, and 2.75c. to 2.90c. for black sheets. A tremendous premium is necessary to secure plates for prompt shipment, while shop-worn sheets have been sold at a cut price for prompt shipment.

In unfinished steel positively shocking prices obtain for steel of special quality. While ordinary soft steel billets are quotable at about \$45, ordinary forging quality commands at least \$20 a ton more, while steel made to war-steel specifications commands almost double price. Ordinary wire rods are quotable at \$60, while \$80 to \$90 is being obtained for rods containing a little extra carbon and manganese. Ordinary rods at \$60, moreover, are not cheap, as they are \$2.70 per hundred pounds, while the regular market price of wire nails is \$2.50 per keg of 100 pounds net weight of nails, with a keg costing about 15 cents thrown in. In the language of the street, "Can you beat it?"

Readers' Views and Comments

Power and Heat for Chemical Plants

To the Editor of Metallurgical & Chemical Engineering

Sir:—I congratulate you on your May 1 issue. There is plenty of inspiration to be found within its covers. Surely applied science is now thoroughly awake in our favored land!

I was especially interested in the papers and in the discussion on the subject of "Power"; the opinion being expressed that under the most favorable conditions, such as cheap coal, cheap transportation, abundant labor, etc., steam might now compete with Niagara power. This is in line with the suggestion I made in your March 15 number, with respect to which you were kind enough to make favorable editorial comment.

Now I desire to bring out a point, in this connection, which seems to have been overlooked; and which I regard of the greatest importance, to-wit: The *advantage* that steam may have over water power where there is a *fair balance* between the *steam heat a plant requires, as such, and heat for conversion into electricity*. The point I have in mind is this: That if it be assumed that 25 per cent of the heat units of the coal is required in the development of electric energy in an electrochemical plant employing steam; *then that plant should be developed for utilizing the remainder of the available heat units of the fuel* (chiefly in the form of the latent heat of the steam) in multiple-stage evaporating, etc. By so doing the electric energy required for the electrochemical work would be largely a by-product. There are many purely chemical operations where a large preponderance of heat over power is necessary.

Finally, it is conceivable that great plants where heat (at low temperatures) is king might well put in electric generators and thus obtain electric energy at very low cost. I think that some day we will have more regard for this principle of "balance." There are great industries in New York City and in practically all manufacturing communities, where the two great forms of energy, heat and electricity, might mutually complement each other. As the situation now stands, we have great central lighting and power stations wasting 75 per cent of the heat units of the coal in condensing the steam. And on the other hand, we have vast sugar refineries and other industries whose chief need is steam-heat. From a heat-standpoint they should operate in combination.

A. C.

Brooklyn, N. Y.

Testing Rubber Insulation

To the Editor of Metallurgical & Chemical Engineering

Sir:—In testing rubber insulation according to the Underwriters' Specifications, the writer found that samples taken from the same coil showed marked variation in strength and elongation. The wire had been in stock some time and the tests were carried out with the idea of putting it in with the new stock, provided the insulation had not deteriorated.

Samples 5 in. long were taken from each coil. They were rolled between two blocks of wood to loosen the insulation. The rubber could then be slipped off the wire. The insulating material was then tested for elongation, stretch and tensile strength.

The results varied as much as 100 per cent, and in only six coils out of fifty-two did the samples check.

The trouble did not lie in non-uniformity or deteriora-

tion of the rubber compound, as was first supposed. The method of separating the wire from the insulation was at fault. No matter how carefully the samples were rolled between the two blocks, the insulation could not be removed intact. In places it would stick to the wire.

A new method was therefore devised for removing the insulation. The wire was tinned copper. Tin amalgamates with mercury very easily and forms a very slippery surface on the copper. The mercury has no effect on the rubber compound. About $\frac{1}{4}$ in. of insulation was cut off of each end of the samples and the stripped wire scraped to remove dirt and grease. The ends of the samples were then immersed in mercury. After a period of time, varying from four to twenty-four hours, the insulation could be slipped off the wire with almost no effort.

This method is being used by one of the largest electrical manufacturers in the country. Besides the accuracy and uniformity of results accompanying the application of this property of mercury, the cost of the testing has been reduced by over one-third.

ARON ARTHUR LADON.

Chicago, Ill.

Experiments on the Electrolytic Production of Hydroquinone

To the Editor of Metallurgical & Chemical Engineering

Sir:—It would seem possible to produce hydroquinone by the oxidation of benzol as well as by the oxidation of aniline, and electrolytic processes, if feasible, would offer the opportunity of obtaining a purer product than any process in which a chemical oxidizing agent is employed. Experiments along this line were moderately successful.

As benzol is a non-conductor, some electrolyte must be used to carry the current, and sulphuric acid seemed to be the cheapest and most satisfactory. The addition of alcohol to the benzol and acid produces a solution, thereby doing away with the necessity of stirring to emulsify, and, as was later noted, increases the yield of hydroquinone. The solution used was as follows:

Ethyl alcohol (95 per cent).....	120 parts by volume
Benzol (C. P.).....	40 parts by volume
Sulphuric acid (Sp. gr. 1.82).....	10 parts by volume
Water	90 parts by volume

The electrolysis was carried out in a glass vessel, using hard carbon electrodes connected in the multiple system. Several runs were made, with different current densities, and at different temperatures.

The solution turns yellow after a few minutes of electrolysis and gradually gets darker, finally becoming a dark brown, probably due to the formation of tar. At the end of the electrolysis, the solution was filtered to remove the tar, a little water was added, and the excess alcohol and benzol distilled off; then boiled with animal charcoal to decolorize, and evaporated almost to dryness. Finally, more water was added, the solution boiled again for a few minutes, filtered to remove the charcoal, and the hydroquinone obtained by crystallization. The product was pure and very white, so that no further purification was necessary.

Low current densities produced the best results, probably due to the fact that the temperature was much lower because of the less I'R heating effect. It was found to be of advantage to place the containing vessel in an ice-water bath. The best results were obtained

with a current density of about 1.5 amperes per square decimeter, an electromotive force of 5 to 6 volts, and at a temperature of 5 deg. to 10 deg. Centigrade, the average yield being about 25 grams per kilowatt-hour. No doubt there would be less decomposition of the product at even lower temperature, but the increase in resistance of the solution would offset this advantage. Neither anodes nor cathodes were attacked in the least as far as could be determined.

This process seems worthy of further investigation, especially to find some method of preventing the formation of tar during electrolysis, and to increase the current efficiency. The simplest explanation of the reaction is the oxidation of benzol by the oxygen produced at the anode by the electrolysis of sulphuric acid. $C_6H_6 + O_2 = C_6H_5(OH)_2$. The alcohol may act catalytically, or may simply have the effect of bringing the molecules of benzol into more intimate contact with the anode than would be possible in the case of an emulsion of benzol and acid, even with vigorous stirring.

A. R. GREENLEAF.

Wakefield, Mass.

The Western Metallurgical Field

Use of Slide Rule in Calculating Base-Bullion Assays

The assay of base-bullion is a comparatively simple metallurgical process; but in the course of its evolution from an unreliable and varying assay to a remarkably trustworthy and uniform one, lengthy and tedious calculations have been required. The following notes will serve to trace the steps of the evolution referred to and show the expedients which have been devised at one of the Denver laboratories to overcome the tedious calculations that formerly were necessary.

Neglecting the step of cupellation, which is the same under any scheme of preparing the buttons and calculating the final result, base-bullion assaying has progressed through five distinct stages or methods of procedure.

1. The sample of from 5 to 7 pounds, however obtained from the lot it represents, is melted and cast into a mold about 5 in. wide by 7 in. long. The bar thus formed is cut longitudinally into halves, one of which is reserved and the other assayed. The manner of taking the individual cuts from the second half is determined by a template locating four areas as shown in Fig 1, the slugs being cut from the bar and clipped to

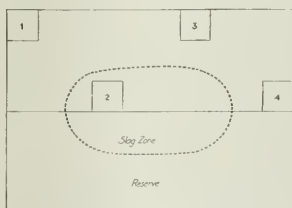


FIG. 1—TEMPLATE FOR BASE BULLION SAMPLES

weigh exactly $\frac{1}{2}$ A.T. Due to the position of these points relative to the slaggy zone and to the more rapidly cooled sides, the resulting assays vary widely as shown by the following typical figures.

No.	Weight of Button	Oz. Ag Per Ton
1	110.02	220.04
2	108.10	216.20
3	109.70	219.40
4	109.26	218.54
Average	109.27	218.54

The four corresponding gold assays will show much greater divergence, increasing with the richness of the bullion.

This method gives the least accurate determination of the value of the bullion, but offers the simplest calculation. Since the slugs are cut to weigh exactly $\frac{1}{2}$ A.T., it is necessary only to multiply by two the weight in milligrams of the cupellation bead.

2. The lot sample, however obtained, is melted, and "gum drops" are cast therefrom by using a small ladle and conical mold. Each of the "gum drops" weighs slightly over $\frac{1}{2}$ A.T., and is clipped to exactly that weight for cupellation. The resulting procedure and calculation are the same as in case 1. This method gives a greater uniformity of individual assays and a more accurate determination of the bullion value, with a simple method of calculation.

Gum Drop	Weight of Button	Oz. Ag per Ton
1	109.20	218.40
2	109.15	218.30
3	109.40	218.80
4	109.35	218.70
Average	109.275	218.55

3. The lot sample is made into "gum drops" as in case 2, but instead of clipping to an exact weight of $\frac{1}{2}$ A.T., each drop is weighed whole with ordinary gram weights, and the weight converted into the corresponding A.T. equivalent. The silver bead is weighed in milligrams, and the assay calculated by proportion arithmetically or by the aid of logarithms. This method gives the most accurate determination of the bullion value, but involves the most lengthy and tedious calculation.

Weight of Gum Drop in Grams	Weight of Button in Mg.	Oz. Ag per Ton
14.18	106.2	218.44
13.72	102.8	218.53
15.15	113.6	218.69
14.15	106.0	218.49
Average	106.2	218.54

$$14.18 : 106.2 :: 29.166 : (X) 218.44$$

4. The lot sample is melted and made into gum drops as before, and each is weighed whole by means of decimal A.T. weights. The silver beads are weighed in milligrams. This method gives as accurate a determination of bullion value as in case 3. The calculation is simpler, obviating the conversion of the weight of the gum drop from grams to A.T., but it still involves one long division for each button.

Weight of Button in Milligrams	Weight of Gum Drop in Decimal A. T. Weights	Oz. Ag per Ton
106.2	0.4861 +	218.44
102.8	0.4704 +	218.53
113.6	0.5194 +	218.69
106.0	0.4851 +	218.49
Average		218.54

5. The lot is sampled and the gum drops and silver beads are weighed as in case 4. The calculation is made with a 20-in. slide rule. This method gives the same degree of accuracy in determining the bullion value, and affords a very simple, rapid and sufficiently accurate method of calculation.

Weight of Button in Mg.	Weight of Gum Drop in Decimal A. T. Weights	Slide Rule Calculation	Oz. Ag per Ton	Arithmetic Calculation
106.2	0.4861 +		218.5	218.44
102.8	0.4704 +		218.5	218.53
113.6	0.5194 +		218.8	218.69
106.0	0.4851 +		218.5	218.49
Average			218.57	218.54

A further illustration comparing the slide rule and arithmetical results on a lot of eight gum drops is given below.

By Slide Rule	By Arithmetic
172.6	172.7
171.8	171.9
171.8	172.0
172.2	172.3
171.2	172.3
171.5	171.5
172.2	172.2
172.2	172.1
Average	172.06

Since an accurate assay of base bullion requires from 4 to 16 cupellations for each lot, depending on the grade and purity of the bullion, the accuracy of the determination is affected by the methods of procedure outlined above. In the old short methods, 1 and 2, accuracy is sacrificed to simplicity of calculation. In 3, we gain accuracy only through such tedious calculation as to prohibit the assaying of a large number of samples within the time that can be given such work by the assayer. By method 5, however, accuracy of assay and simplicity of calculation are combined to great advantage. Decimal A.T. weights reading to 0.0002 A.T. can be procured from weight manufacturers, and the 20-in. slide rule read under a large magnifying glass gives results well within the limits of accuracy of cupellation. The method is in successful use in umpire work on Western lead bullions.

Accidents at Metallurgical Works

For the first time since its organization the Bureau of Mines has made a report on accidents at metallurgical works, covering smelting, milling and refining plants for gold, silver, copper, lead, zinc and quicksilver, and iron-ore washers. Iron blast furnaces are not included. The report, issued as *Technical Paper 124*, is for the calendar years 1913 and 1914, during which time 119 men were killed, 2285 seriously injured and 11,046 slightly injured. These figures represent fatality and injury rates of 1.55, 29.67 and 143.44, respectively, per 1000 men employed.

An arbitrary classification of slight and serious injury was made on the basis of time lost by the injured man, 20 days being the dividing point. This basis will be changed for the 1915 report to conform with the classification adopted in the States now having compensation laws, as follows:

1. Fatal.
2. Serious (time lost, more than 14 days):
 - (a) Permanent disability.
 - Total.
 - Partial.
- (b) Others.
3. Slight (time lost, 1 to 14 days, inclusive).

The statistical tables given in the report show a lower accident rate in ore-dressing plants than in smelters. Classified according to causes, the accidents appear as follows:

Cause of Accident	Ore-Dressing Plants			Smelting Plants		
	Killed, Per Cent	Slightly Injured, Per Cent	Seriously Injured, Per Cent	Killed, Per Cent	Slightly Injured, Per Cent	Seriously Injured, Per Cent
Haulage	12.8	9.6	6.9	25.0	14.0	9.7
Machinery	25.6	28.9	16.5	18.7	9.0	5.4
Falls of persons	15.4	16.0	12.4	26.0	13.8	9.5
Suffocation in ore bins	1.7	16.0	23.8	5.0	14.7	17.1
Flying or falling objects	15.4	1.7	1.4	5.0	.6	1.2
Electricity	7.7	5.3	10.5	6.9	10.9	
Hand tools	1.1	5.1	...	3	2.1	
Nails, splinters	...	...	...	...	...	...
Burns (steam, water, molten slag)	1.0	1.0	11.3	26.7	20.6	
Other causes	15.4	20.4	22.3	11.3	13.8	23.1

The greater use of machinery in mills than in smelters undoubtedly explains the relative figures in that item, for in the former the men are in closer contact with jigs, tables, stamps, rolls, crushers, belts, wheels and shafts. In other items the figures are reversed, due to the prevailing conditions. The report serves a useful purpose in directing attention to the cause of accidents and will serve as a guide for improving conditions.

Symposium on Flotation

At the flotation conference held at Lawrence, Kan., Jan. 28 and 29, 1916, the proceedings of which were reported in this journal Feb. 15, a questionnaire on flotation was formulated as a basis for a proposed symposium

on the subject at the Arizona meeting of the American Institute of Mining Engineers next September. These questions are designed to bring out information on the theoretical and practical phases of flotation, either by way of formal papers, discussion or suggestions for research. By giving publicity to the matter well in advance of the meeting, it is hoped that the symposium will be a marked success. The questionnaire follows:

Practical questions:

1. What is the effect of dilution of a pulp with water on the flotation of the minerals contained?
2. Is agitation of a pulp necessary for all froth flotation?
3. Is there a fundamental difference between "pneumatic" froth and "mechanical" froth?
4. Are ores that produce much finely divided, or flocculent material, harder to treat successfully by flotation than those which do not contain much of this "colloid" material?

Questions on Oils.

1. Is an "oil" necessary for froth flotation?
2. What is the effect of the addition of an excess of flotation oil?
3. Upon what does the necessary quantity of oil depend—the quantity of sulphide minerals present, the amount of air entering the froth or the amount of water present relative to the ore?
4. Is the function of oils to cause selective adherence of air bubbles to sulphides or is it to assist in the formation of a froth?
5. Are the bubbles in a froth mantled with oil or is it sulphide minerals which are coated, or is the effect of the oil in some way connected with modification of various properties of the water?
6. Is it the soluble or the insoluble portion of an oil which assists frothing?

Theoretical Questions.

1. What is the real effect of other addition agents, such as alkalis, or acids, or copper sulphate in the flotation of sphalerite?
2. In what way can surface and interfacial tensions explain froth flotation?
3. How can electric charges on minerals explain flotation?
4. Has "flocculation" (as applied to colloids) anything to do with flotation?

Flotation of Copper Ore in Canada

The Sable River Mining Co. is reported to be the first to install a Callow flotation plant for the treatment of copper ores in Canada. The company's property is near Massey, west of Sudbury. The ore is chalcopryrite containing 3 per cent copper and is said to float readily. The oil mixture is wood creosote, crude turpentine and pine oil with a small amount of coal tar and coal tar creosote. The plant will have a capacity of 50 tons per day and is intended to treat reground tailings from Wilfley tables.

Renewed Activity in the Tungsten Mines at Atolia, Cal.

The rise in price of scheelite, one of the five tungsten ores, has built up what is said to be one of the largest tungsten camps in the world at Atolia, Cal., which is 60 miles from Barstow out on the Mojave desert. There are three tungsten districts in the vicinity, the Atolia, the Stringer and the Rand. The latter has been a steady producer of gold for 30 years and only recently have the properties been worked for tungsten. The Atolia district is 3½ by 10 miles in area and in December the main camp consisted of only a few tents. Recent interest in the development of the properties has been

such that at the present time the population is estimated at more than 2000. Three carloads of high-grade ore were shipped during the fourth week in April by the Atolia Mining Company and plans are now under way for remilling the dump of this company, which has been accumulating for many years and which contains 5 per cent ore. It is estimated that at prevailing high prices \$3,000,000 worth of metal can be extracted from the dump. Just what price the company secures for the metal is not known, but \$5 per pound has been suggested as an approximation.

Non-Ferrous Metal Market

Wednesday, May 10.—The outstanding feature in the market during the last two weeks has been the sensational rise in the price of silver, which advanced over 10 cents since our last report, due to demand from Europe and the Far East for coinage purposes. During the last few days, however, it has reacted somewhat from its high mark of over 77 cents. The other metals have either remained stationary or have registered short declines, due to dullness in most cases.

Copper.—Copper prices have remained practically stationary during the last two weeks, although it was the strongest metal on the list outside of silver and was in marked contrast to spelter, lead, tin and antimony. The exports for April were 21,000 tons. It is understood that very little copper is available even for the last quarter. The American Metal Market report gives the quotations as follows: Prime lake, 29.75 to 30.25; electrolytic, 30.50 to 31.00; casting, 27.75 to 28.25.

Tin.—Futures have been in good demand, while the spot market has been comparatively dull. Dealers have been disinclined to sell on account of the uncertain future of the market. The obtaining of shipping permits is difficult and is one of the main controlling factors in the market. Straits tin is quoted at 49.75 spot.

Lead.—The lead market has been very dull and has brought out some cheaper offerings by second hands. The Trust price is still 7.50 cents, while outside prices are $\frac{1}{8}$ to $\frac{1}{4}$ cent lower.

Spelter.—Spelter has been dull and has declined about 1 cent per pound. The market is spasmodic as regards buying and no sustained demand has occurred. May spelter is quoted at 16.75, June at 16.25 and third quarter at 15.05 to 15.30. Spot quotations are 16.93 $\frac{1}{2}$ to 17.17 $\frac{1}{2}$.

Other Metals.—*Antimony* has been very dull and has declined 4 cents to 36 cents. There have been quite a few sellers, but customers have not shown a disposition to buy. *Platinum* remains nominally quoted at \$85.00 and *silver* is now at 73 $\frac{1}{4}$ cents, 4 cents below its high point on May 3. *Mercury* has dropped further, to \$110 per flask.

The Iron and Steel Market

The general trend of steel prices is still upward, but the rate of advance is very slow, there being only sufficient advances to show that the market is strengthening rather than losing ground. As a matter of fact steel prices are not at this juncture a good index to the state of the steel market or the prospects of the trade. A better index is the pressure upon the mills for delivery of material already contracted for, while the future of the trade hinges largely upon the supply of workmen and their willingness to do a full day's work each day, in both the steel-producing and the steel-consuming industries. Another element that will help to shape the future course of the steel trade is transportation, the ability of the railroads to carry the freight offered.

While practically all steel products advanced sharply during February and March, the advances since April 1, for deliveries at mill convenience, have been only sporadic. In April sheets advanced \$1 a ton, tin plate 50 cents a box and pipe and boiler tubes \$4 a ton and more, according to size. May 1 plain wire advanced \$4 a ton and wire nails and barb wire \$2, while since then tin plate has advanced another 50 cents a box. Some of the mills have stiffened in their plate quotations, the Carnegie Steel Company having adopted 2.90c. as its regular quotation.

Labor Troubles

The unrest in the ranks of labor has steadily increased, and this has taken the particularly unfortunate turn of men demanding a shorter workday at a time when there are not enough men to do the work in hand if all worked the customary hours. Strikes on May 1 for an eight-hour day for machinists were not as general as labor agitators had expected, but were serious nevertheless. The machinists employed at the East Pittsburgh plant of the Westinghouse Electric & Manufacturing Company struck late in April, and early in May unorganized mobs of strikers and others began raiding various industrial plants in the neighborhood for the purpose of forcing men to strike. The most violent attack was made upon the Edgar Thomson Steel Works at Bessemer, the mob being confronted at the entrance by a heavy guard, who fired and killed two or three men, wounding others. The militia was called out and restored order. The Westinghouse strike itself is now practically over, many men returning to work at rates formerly prevailing.

The wage advance in the steel industry, averaging about 10 per cent, went into effect May 1, except that the advance in the Connellsville coke region became effective May 8. Labor in the steel industry is fairly well satisfied, but the supply is insufficient. In the steel-consuming industries it is likely there will be strikes at various points as long as the industrial pressure continues. It is a question whether either the production or the consumption of steel can be maintained at the rate the orders on books and the physical capacity of plants would permit, but whether the trouble will be of such a nature as to make steel more plentiful or more scarce cannot be forecast.

The inadequate supply of labor in the steel industry affects the work upon steel mill extensions much more than the operation of plants already in existence. Construction work is proceeding much more slowly than was expected. The general statement is made that work on by-product coke ovens has been proceeding slowly, that practically all the jobs are three months or more behind schedule. Much the same statement could probably be made with respect to additions to steel-making capacity.

Greater Pressure for Steel Deliveries

Activity in the far forward deliveries has decreased farther, and the market in this respect is extremely quiet. Confronted with prospects of so much labor trouble both producers and consumers of steel are chary about making commitments for the far future. Consumers are certainly exerting more pressure upon mills for delivery of steel already bought, but whether this is because more steel is needed for ultimate consumption or because buyers fear that they may not be able to fabricate it as well later, or that the mills will not be able to produce later at their present rate, can scarcely be determined in the confused state of affairs in the trade.

Pig Iron

Apart from a recent drive made by Buffalo furnaces, whereby a large tonnage was disposed of at slight cuts from prices formerly ruling, the pig iron market has been extremely dull in practically all sections. Prices have not yielded elsewhere, and may be described as firmly maintained despite—or perhaps because of—the lightness of inquiry.

Expectations entertained for many weeks in certain quarters that a buying movement would develop in pig iron, and disclose a shortage in productive capacity as compared with consumptive requirements, continue to be disappointed. It seems now to be well established that the country cannot make more pig iron than it has been making lately, the rate being a shade under 40,000,000 tons a year, and production may indeed decrease as warmer weather arrives. The expected increase in steel mill requirements has not developed. The abnormally heavy production of scrap is assigned as one cause, but another may be that work on steel plant extensions is proceeding slowly and additional pig iron is not likely to be required as soon as expected. We quote No. 2 foundry iron, delivered Philadelphia, \$20.25 to \$20.75; f.o.b. furnace, Buffalo, \$19 to \$19.25; delivered Cleveland, \$19; f.o.b. furnace, Chicago, \$19; f.o.b. Birmingham, \$15 to \$15.50; f.o.b. valley furnaces, 95c. higher delivered Pittsburgh; Bessemer, \$21 to \$21.50; basic, \$18.25 to \$18.50; foundry and malleable, \$18.50 to \$19.

Unfinished Steel

There has been a slight increase in offerings of soft steel billets and sheet bars, but with the market not quotably changed, what are regarded as regular prices being \$45 for Bessemer and \$45 to \$50 for open-hearth, with rods at about \$60. High-carbon, forging and war specification steels all show a further advancing tendency. There is a fairly heavy inquiry for shell steel for delivery throughout 1917, quite out of keeping with some recent predictions on this head. Forging billets are quotable at \$65 and upwards, while war billets might bring as high as \$90. High-carbon rods have sold up to \$90.

Finished Steel

Regular prices, for delivery at mill convenience, are 2.50c. on bars and shapes and 2.75c. to 2.90c. for plates, plates for prompt shipment ranging up to 4c. Sheets, particularly blue annealed, have advanced a trifle. Wire prices were officially advanced May 1 by \$2 a ton on nails, polished staples and barb wire and \$4 a ton on plain wire, both bright and galvanized. Nails are now on the basis of \$2.50, but some producers are quoting \$2.60.

Award of Willard Gibbs Medal to Willis R. Whitney

The Willard Gibbs Medal has been awarded to Dr. Willis R. Whitney, director of the research laboratories of the General Electric Co., Schenectady, N. Y. The medal was founded by William A. Converse of Chicago and has been presented to four other prominent chemists. Presentation will be made at the meeting of the Chicago Section of the American Chemical Society, on May 19, when Dr. Whitney will make an address on "Incidents of Applied Research."

Society of Chemical Industry.—On Friday, May 19, Dr. Raymond F. Bacon, director of the Mellon Institute, Pittsburgh, will lecture before the New York section on "Some Problems of the Petroleum Industry."

Nitre Cake in Sulphate of Ammonia Manufacture

Some interesting data on using nitre cake as a substitute for sulphuric acid in the manufacture of sulphate of ammonia are given in *The Iron and Coal Trades Review* (London), April 14, 1916. The data are taken from recommendations made by the (British) Sulphate of Ammonia Association. The use of nitre cake is only advocated as a temporary expedient since it is not deemed advisable to reduce the percentage of ammonia in the sulphate to under 25 per cent. With the use of nitre cake the percentage is 24 or less. The recommendations are based on the practical experience gained at a large works which used nitre cake on a working scale over a considerable period; it will be seen that there are dangers to be guarded against, which are not apparent in mere theoretical or laboratory work. The average composition of the salt produced at the works in question was: Ammonia, 24.01 per cent; free acid, 0.88 per cent; moisture, 2.70 per cent; Na_2SO_4 , 3.20 per cent, corresponding to a consumption of over 7 per cent of nitre cake, equal to about 2½ per cent of acid saved.

There are two sources of nitre cake: (1) From sulphuric acid plants; (2) from nitric acid plants. The nitre cake from the first source usually contains 20-35 per cent of free sulphuric acid with traces of nitric acid, and from the second source 30-40 per cent free sulphuric acid, and up to 2 per cent or even more of nitric acid. The presence of free nitric acid causes serious damage to the lead work of the saturator, and ultimately destruction of ammonia, and too much care cannot be taken in guarding against the presence of this substance. The danger is emphasized at the present time, when nitric acid plants are very hard pressed, and it is not profitable to the nitric acid manufacturer to remove the last 1 or 2 per cent of nitric acid from the nitre cake. The maximum percentage of nitric acid in the nitre cake used by sulphate of ammonia makers should be 0.05 per cent.

The use of a quantity of nitre cake exceeding 10 per cent by weight of the acid except in special circumstances is not recommended. The nitre cake should be dissolved in water until the solution shows 48.5 deg. Bé. at 200 deg. F. Mother liquor from the saturator may also be used for dissolving the nitre cake. This solution must be run into the saturator as hot as possible, and continuously with the acid. The best working strength is 41.5 to 43 deg. Bé. and the salt produced will vary from 23 to 24 per cent ammonia. With the solution of nitre cake in water of the strength mentioned above, one volume of solution should be used with every ten volumes of 70 per cent chamber acid; or its equivalent.

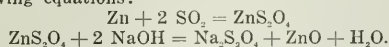
The difficulties encountered when using large quantities of nitre cake are as follows: (1) Precipitation of sulphate of soda on adding the nitre cake to the saturator. This causes the production of an irregular quality of salt containing anything down to 15 per cent ammonia. (2) Irregular working of the bath owing to the impossibility of control without frequent titration. The latter is not possible at the present time. The salt produced often contains 2 per cent of acid after leaving the centrifugal machine, and in this case moisture is absorbed in store, and it is not possible to pack the product in bags. When the quantity of nitre cake used is less than 10 per cent by weight of the acid, these difficulties are partially overcome.

Manufacture of Sodium Hydrosulphite in the Sugar Factory.—The following data on hydrosulphite of soda are taken from *The Chemical Trade Journal and Chemical Engineer* of April 22, 1916. Hydrosulphite of soda,

$\text{Na}_2\text{S}_2\text{O}_4$, which previous to the war was sold as a white salt under the trade name of "Blankit," and manufactured by the Badische Anilin und Soda-fabrik, is a powerful bleaching agent, the use of which seems now well established in the sugar industry. Although it may be true that it has not entirely realized all the advantages predicted of it by its makers at the time of its first appearance on the market, there appears to be no doubt whatever that it is a most valuable decolorizing agent in the manufacture of white sugar. Since the outbreak of the war, hydrosulphite of soda in the form of powder appears to have been unobtainable, excepting in small occasional quantities and at extortionate prices, and it is certain that white sugar manufacturers in different parts of the world have felt keenly the deprivation of this commodity.

It is therefore a matter of much interest, says the *Int. Sugar Jour.*, to announce that M. Louis Deschamps, a well-known French chemist, after some years of experimental work, has now evolved a process which can be installed in the sugar factory or refinery for the manufacture of the bleaching agent in the state of solution ready for use. The plant used is comparatively simple, and for its operation the supervision of a chemist is not necessary, the services of an intelligent workman only being required. The principle of the method is first to obtain hydrosulphite of zinc, which is readily done by acting on metallic zinc with a solution of sulphurous acid.

By treating the solution of hydrosulphite of zinc thus formed with caustic soda, a solution of hydrosulphite of soda results, which procedure is illustrated by the following equations:



Whereas formerly, liquefied sulphur dioxide was necessary for the process of manufacture, this product (largely of German origin) is now no longer indispensable. Ordinary sulphur oven gas being inadmissible for the purpose, owing to its content of free oxygen, M. Deschamps has devised a special oven producing sulphurous acid gas quite free of oxygen, though containing nitrogen, which is an inert gas not interfering in any way with the reaction. It is the invention of this oven that renders the process of making hydrosulphite a practical one in the tropics, since it obviates the necessity of using liquefied sulphurous acid gas in cylinders, which are both costly and difficult to transport.

American Carbide Plant to Be Built in Norway

The Union Carbide Company, Niagara Falls, has started the erection of a large calcium carbide plant at Saude, about 60 miles from Bergen, Norway. The plant will buy its power from the Aktieselskabet Saude Faldene, and the power is to be furnished beginning Jan. 1, 1918. In the meantime the plant will be constructed. At first 20,000 hp. will be used. This will later be increased to 40,000 hp. The company's American and Norwegian engineers from this country will go over to superintend the construction.

One reason for the establishment of the plant in Norway is that much cheaper power can be obtained than in this country. Cheap labor is also available, and under normal conditions cheap freight rates can be obtained. The company plans to take care of its export business from this plant, and also its coast business in this country. In other words, carbide can be made over there and shipped back here cheaper than it can be made here.

Research and the Newlands Bill

BY WILLIS R. WHITNEY

For a good many years our colleges have been teaching their students the arts and sciences, and more lately, even preparing them for routine service in the technical industries. But for over two-score years Germany has carried education a step further. In our institutions of learning we devote most of our efforts to the undergraduates, bringing them up to a certain limited, but useful state of development. We have failed to prepare any considerable number of men for advanced scientific work, and have neglected the need for extending the boundaries of scientific knowledge. For this reason we, together with many other countries, have had to depend on German Universities for the training of our research workers and teachers. Going to Germany for the doctors' degree has had reason behind it.

The picture accompanying this note was taken in 1856, at the Goettingen laboratory of Professor Woehler. It shows advanced students of chemical research from many lands. Two or three of them are Americans.



WOEHLER'S RESEARCH STUDENTS 1856

Under Woehler's direction were carried out the first successful experiments on the production of organic compounds from laboratory products. These experiments opened the way for all the subsequent organic syntheses; dyes, medicines, rubber, and many thousands of useful products. Woehler also produced the first metallic aluminium, now made in this country at the rate of 30,000 tons per year.

The picture shows but one of the successive groups of men who came under Woehler's influence. And Woehler was but one of the scores of scientific leaders who made possible Germany's phenomenal industrial and manufacturing development. How many such groups of advanced students can be found even at this late day in America?

We should do all we can to bring about the establishment of this kind of effort in our United States. It could be done as it has been done in so many cases in Germany, by encouraging the scientific men of our colleges. Most of them are now so exhausted by undergraduate teaching, and discouraged by financial conditions, that research seems impossible. When we recall the successful teaching and research work of such men as Liebig, Woehler, Ostwald, Nernst, Roentgen, Hertz, Van't Hoff, Haber, Wien, Fischer, Baeyer, Bunsen, Kirchhoff, Helmholtz, and many more, who were teachers of the sciences, but also active workers in them, we must deplore the short-sighted method of confining our

scientists to teaching, to the entire exclusion of the practical experimental work demanded by our need for new knowledge. Consider the sheer waste of intellect. There is no other field calling so acutely for conservation. And the nation needs what these men might give it. Thus far we have been depending upon others to produce the new knowledge, trusting to the gleanings of their harvest to furnish us seeds for a second crop of mechanical inventions and adaptations, forgetting too long that growth and continued prosperity come only to those nations which are responsible for the original research work, and not for the storage or conservation of knowledge.

The most natural and economical way of attempting to improve our national condition in this respect would be to encourage our college professors of the sciences—physics, chemistry, electricity, mechanics, etc.—to do research work, to gather about them groups of post-graduates, who would co-operate in the lines of experimental work which the knowledge or interest of the particular teacher dictated. A very few are already doing this, but it is only in biological research that the activity is very noticeable.

The Newlands bill No. 4874, providing for the establishment of an "engineering and mechanics' arts" experimental station in connection with the Land Grant College of each state, seems to be a start in the right direction. It is planned thereby to do for the industries what has already been done by similar bills for agriculture. The plan has been highly developed, and proved very successful in the latter field. This bill seems to be a constructive, active attempt to do something farsighted for the future welfare of our country, and is certainly a part of wise preparedness. It should discover and bring forth a great deal of the separated and remote scientific talent of the country, and assist it to work along the lines best suited for producing new knowledge, trained investigators, and inspired teachers. By effective co-operation under the supervision of a federal department it should lead to well advised efforts in the arts without that duplication which is now a drawback of isolated research. The plants exist in the present colleges, together with a picked class of men. Hence there is economy in the plan proposed by the Newlands bill.

It seems to me probable that if federal aid were given the Land Grant Colleges for this purpose, there would take place what occurred when this was done for Agricultural Research. The separate States seeing the advantages, and realizing that a start had been made, would also give aid. In 1913, the federal appropriation for agricultural experiment stations amounted to \$1,545,000, and additional financial aid rendered by the States aggregated \$1,807,016.

Of the agricultural work accomplished, Dean Bailey of Cornell, has written:

"In 1887 Congress passed a bill providing that \$15,000 in money be appropriated to each State for the organization and conduct of an experiment station in connection with its agricultural college. Two facts had become painfully apparent. One was that the lands of the original grant had been largely wasted, and the other, that agriculture lacked a body of exact scientific data on which to establish courses of reliable instruction. Accordingly, the Hatch bill appropriated money instead of lands, and made rigid provisions for its expenditure along agricultural lines and for research only. In spite of the utmost precautions some of these funds were absorbed in teaching by institutions still embarrassed for funds, and by men who scarcely knew the meaning of research, or if they did, were ignorant of how to conduct it.

"But in time, and even in a surprisingly short time, results began to appear. There were men who knew how to discover the laws on which plant and animal growth depend, and those on which the soil produces, and gradually the scientific principles underlying agricultural practice began to be established. Moreover, these principles worked when tested out in practice, and for the first time, young men fresh from college, but in possession of these principles, succeeded better than had their fathers, though to the art and manner born. That was what made agriculture respectable in the university, and about 1905 the subject had gained a permanent standing in some of the best of the State Institutions, which means that at last it was, alongside other great fields of inquiry, challenging the abilities of the best scholars of the times."

President Thompson of the Ohio State University said: "The experience and history of the land grant colleges have brought industrial education to its rightful place in the esteem of the American people, and have forced its recognition by all institutions of higher education."

The day upon which a similar statement may be made concerning scientific research in general will see our country far advanced upon the road that leads to assured National Preparedness. For the only safe and sane preparedness must rest upon that broad and thorough development of the industries which is impossible without a constantly extending knowledge of scientific fact.

Corrosion of Condenser Tubes

No conclusive results, but interesting isolated data are brought out in the third report of the Corrosion Committee of the Institute of Metals (London) presented in abstract at the annual meeting March 29, by Mr. W. E. Gibbs and further abstracted in *Engineering* March 31, together with the discussion. The committee tested five different alloys furnished by the Broughton Copper Company and the Muntz Metal Company. One of the alloys, a phosphor-bronze, contained 3.8 per cent zinc and 0.02 per cent phosphorus, and another aluminium-copper contained 7.92 per cent aluminium, 0.25 per cent iron, and 0.13 per cent silicon. The other alloys were brasses.

One novel point brought out in the new research was that the action of stagnant sea-water varied with the depth of immersion owing to corresponding variations in the air content. Dr. Bengough, immersing his specimens to a depth of 1 in., had found spots of oxychlorides on the upper surface. With the 3 in. immersion adopted by the speaker no such spots were developed. The most important point established was that the dezincification of the brasses in sea-water depended on three things—viz., the aeration, the dilution, and the CO₂ content. The experiments made with pure copper and pure zinc bore out the observations made on the two as alloyed. Aeration of the water in condensers arose from eddies at the mouth of the tubes. Just inside the tube-plate there was thus a "churning" point at which corrosion was marked, and especially in low-temperature tests.

It would appear that the solution of copper in sea-water depended very largely on the dissolved salts and was reduced by dilution. With zinc, on the other hand, the rate of solution increased as the concentration diminished, being greatest in distilled water. Carbon dioxide, moreover, played an important part in the solution of zinc. In the absence of CO₂ there was practically no solution of zinc in sea-water saturated with air, whilst the process was rapid in sea-water free from air

but saturated with CO_2 , and brass behaved similarly. The formation of the oxychlorides depended on the range of temperature and on the concentration of the salts.

It had been proved that local electromotive forces, due either to temperature differences or local variations in composition, played a large part, and an important point for settlement was the discovery of what protective electromotive force sufficed to afford security. He had tried the effect of coke, and found that Mr. Arnold Philips was right in the view that its presence might accelerate the solution of the zinc. In practice, however, the conditions in which it might act thus, could seldom arise, as the contact would be generally too poor, both with the metal of the tube and with the sea-water, owing, in the latter case, to the tendency of the pores to get filled with non-conductive deposits. The tests indicated that hard-drawn metal lost weight less rapidly than annealed, but it was more prone to localised attack.

The discussion was opened by Mr. Arnold Philip, who observed that the report was a somewhat monumental document, difficult to discuss, and he hoped that in a later publication it would be possible to marshal the facts in a more attractive form. He suggested that the losses should be expressed as weights lost per square centimeter per unit of time. In their references to aerated sea-water the authors did not make it clear whether the oxygen was dissolved throughout the mass or whether it existed as bubbles. All sea-water contained dissolved oxygen to a considerable amount, and if this were removed very different results would be recorded in corrosion experiments. He agreed that oxygen in the shape of bubbles did have a large effect at what the author called churning points, and it was well known that troubles arose from this cause near the entrance to condenser tubes. The proposal to clean tubes *in situ* with weak acid was new to him, and he would like to see it tried, but on someone else's condenser. The suggestion was a novel one to him, and he would ask whether the authors had any experience of the method.

Mr. S. Smith said the dezincification of brass had been treated with an air of mystery, but the phenomenon was wholly at one with the general behavior of solid solutions. So far back as the eighth century Geber knew that silver could be selectively dissolved from a combination with gold. He could not help thinking that progress would be more rapid if the committee could get away from the study of actual condenser tubes and study the corrosion of the zinc and copper alone. He noted a start in this direction had been made, and he thought this was vitally important. He might add that he had himself found that the rate of solution of silver was greatly modified by the size of the crystal grains. He had noted the same thing in copper, and the difference was accentuated by cold working. With zinc the effect was less marked.

Prof. H. C. Carpenter noted that the copper-aluminium alloy used contained 7.92 per cent of aluminium. It was thus very near the saturation point of the alpha solid solution, and, in fact, in the cast state would contain some beta. On annealing this disappeared, but he should like to know if any were visible in the micro-structure of the tubes used? If the metal was not in thermal equilibrium, then a reduction of the aluminium would probably lead to improved results, as the rate of corrosion of two-phase systems was generally greater than that of single-phase ones. The tabulated results seemed to show this alloy to be superior to all three brasses, while the phosphor-bronze came last; yet Mr. Gibbs recommended that which, on the face of it, appeared decidedly the worst. The fact appeared to be that no one alloy was the best in all conditions, and in

the absence of special protective measures, not one would be suitable for all waters and all temperatures. The copper-aluminium tubes came out exceedingly well, but containing only 8 per cent of aluminium, the first cost would obviously be higher than that of brass tubes, and the important question was whether this difference would be great enough to prevent the use of the alloy as a substitute for brass.

Dr. W. Rosenhain did not agree with Professor Carpenter that the copper aluminium alloy would be improved by a diminution of the aluminium. The remedy for troubles arising from free air was to avoid negative pressures throughout the system. As to accelerated tests, he believed they had their uses, but there was a tendency to adopt them and swallow the resulting observations wholesale and without discrimination. With respect to experiments on the corrosion of zinc, it should be borne in mind that this metal had transformation points at relatively low temperatures, and its actual properties depended largely on its past history, so that on working with it a good deal of care was necessary to make sure of its real condition.

Sir Alfred Yarrow, called upon by the president, asked if the authors of the report had noted any effect due to the speed of the water flow. The experience of his firm had led them to believe that corrosion was much more rapid with low water speeds than with high, and they recommended engineers accordingly to keep up the speed of the circulating pumps, even when a boat was traveling at cruising speeds. The point was of importance, as the rate of corrosion of the tubes often determined the distance the boat could run before being laid up for repairs. He should like to know, therefore, whether he was right in believing that there was less corrosion with a rapid flow of water.

Mr. John Christy said there had been serious trouble with tube corrosion at the plant in his charge. Sea-water was used for circulating purposes, and the tubes gave out in twelve to eighteen months. The cost of replacement amounted to about 1000l., less the value of the scrap. He had tried to protect them by means of zinc, but with only partial success. The zinc was costly to replace and required constant attention, since it was ineffective unless kept clean. He had consulted many leading authorities, and had recently adopted the process which was to be described that evening in Mr. Cumberland's paper. So far this had proved very satisfactory. In this method the electromotive force of the little electrolytic couples responsible for the corrosion was drowned out by a counter electromotive force supplied from an outside source. He had, as stated, found the method very satisfactory so far, and he hoped that the process would be thoroughly investigated by the corrosion committee. He agreed with Sir Alfred Yarrow that the corrosion was worse at low-water speeds.

Mr. Rolfe, who followed, observed that it was a *sine qua non* that remedies for corrosion should not diminish the efficiency of the condenser, and certain of the recommendations made in the report must be regarded from this standpoint. The rate of flow which it was possible to adopt for a condenser was severely restricted. If not enough water was put through, the top tubes became ineffective, while if the quantity was too large, the cost of pumping became too high. There was thus some intermediate rate of supply which best suited the conditions. In power-station practice, with condensing water entering at 65 deg. Fahr. and leaving at 84 deg. Fahr., the quantity supplied was about 55 lb. of condensing water to 1 lb. of condensate. In all condensers, moreover, the velocity of flow must exceed a certain critical value. If below this, the water flowed through without turbulence, with the result that there was a

cold core in the center of the tube and a hot outside layer. In practice the velocity ranged from 4 ft. to 8 ft. per second. Applying these considerations to the recommendation to substitute parallel for series flow in condensers, this would mean that if the same quantity of water were sent through a four-flow condenser, the velocity would fall too low. The result would be a bad vacuum and a great loss of efficiency. If, on the other hand, it were intended to keep the velocity up to the normal value, four times the quantity of water would have to be pumped, which, as the static head would be 20 ft. or more, was a serious matter. The abolition of eddies might reduce corrosion, but it would at the same time seriously lower the efficiency of the condenser. The proposal to remove oxychloride deposits by means of acid (he presumed acetic acid would be used) had been dealt with by Mr. Philip, and would certainly require exceedingly careful control. As to the suggested cause of corrosion, to be satisfactory this must account for the concentration of the corrosion in the bottom of the water surface of the tubes; 90 to 95 per cent of the failures occurred here, there being often very great pitting at the bottom, while the tops and sides of the tubes were not very much affected. This could not be explained by any theory which attributed corrosion to local differences in the physical condition of the tube. Whether it might be due to the action of oxychlorides was more debatable, if the oxychlorides fell to the bottom of the tube; but if they stuck all round the tube, their action would not account for the excessive corrosion at the bottom which was always observed. The speaker believed that the entrance of cathodic particles into the tube was the main responsible cause, and that protection would be best secured by providing a counter electromotive force from an outside source.

At the opening of the evening sitting, Mr. Rolfe exhibited a condenser tube which showed very severe pitting on the steam side. This tube proceeded from the condensers of a land power station in which hundreds of tubes per year failed in the same way. The feed was peaty water, very soft, and the circulating water was sea-water. It was a remarkable fact that the pitting started and continued on the steam side and not on the water side. This was very interesting, since extreme corrosion took place generally on the water side. He (the speaker) thought there was more CO_2 in peaty water than in ordinary water, and Section V of the report, which dealt with corrosion in solutions other than sea-water, pointed out that a large amount of CO_2 in the water formed a very virulent solution. Peaty water, therefore, containing free CO_2 , should not be used as it was, but lime should be added to it to get rid of the CO_2 .

In the reply to the discussion, Mr. W. E. Gibbs said in their report the authors had stated that when fresh sea-water was tested with phenolphthalein it showed no trace of alkalinity, while if it were allowed to stand one night, the surface water became faintly alkaline; the speaker added to this statement that the less salt there was dissolved in the water the greater was the proportion of free CO_2 . This point, he thought, might bear upon the results obtained in sea-water. The report had described the aeration very fully. This was of two sorts, a gentle and a violent aeration. In the gentle aeration, the motion of the water relatively to the surface of the metal was as small as possible, while in the violent sort the air current flowed through a large orifice and impinged directly upon the metal. The violent aeration was more effective in the production of zinc oxychloride on the surface of the metal than the gentle sort.

He was very glad to hear Mr. Smith emphasize certain sections of the report, and he (the speaker) felt

strongly that the best course to pursue was first to deal with pure metals, and then to deal with more complicated alloys, while in regard to corrosion he felt that it would be necessary to define it in the future more accurately than had been done in the past. He hoped Mr. Smith would put before the Institute the details of his own researches. In reply to Professor Carpenter, the corrosion committee had not examined other copper-aluminium alloys. The chief trouble met with was local pitting, and they had taken phosphor-bronze as best resisting this. But no one alloy had been found to satisfy all conditions; one given alloy resisted one effect, and another alloy resisted another. Dr. Rosenhain had referred to the bulk of the report; he (the speaker) would have liked to have been able to reduce it, but it was difficult sometimes to see a work in the true perspective when standing too near it.

There was a large future for experiments with copper-aluminium alloys containing deoxygenizing additions, such, for example, as vanadium. He (the speaker) had had an instance put before him of such an alloy containing 2 per cent of vanadium which stood remarkably well. The local corrosion of propeller blades was most interesting, and it had, no doubt, been due to the presence of local air-pockets. In condenser tubes on board ship the circulating water came in from the bottom, and under certain pressure conditions air was liberated to some extent, and there occurred a churning action, liberating air, apart from any effect due to the rise in temperature. The statement to the effect that it was necessary to bring the whole of the circulating water in contact with the hot condenser tube was most interesting. The zinc used in the corrosion committee's experiments was pure Brunner-Mund zinc, cast and cleaned. Mr. Rolfe's reference to corrosion occurring on the steam side of condenser tubes was also most interesting; the occurrence was, however, not new. The researches the committee had carried out had been essentially physicochemical researches, and he believed that without sound physicochemical work the problem of corrosion could not be solved.

Two Scholarships in Chemical Engineering

The Chemists' Club of New York announces the establishment of two scholarship funds, the income from which (approximately \$500 per year in one case and \$400 per year in the other case) is to be devoted to assisting financially deserving young men to obtain education in the field of industrial chemistry or chemical engineering. Its benefits will be open to properly qualified applicants without restriction as to residence, and may be effective at any institution in the United States which may be designated or approved by The Chemists' Club. Applicants must have completed a satisfactory high-school training, but preference will be given to young men who have supplemented this with additional academic work, especially in subjects which will form a suitable ground work for the more advanced study of applied chemistry and chemical engineering. All inquiries should be addressed to the Bloede Scholarship Committee or the Hoffmann Scholarship Committee of The Chemists' Club, 50 East Forty-first Street, New York City. Applications for the academic year 1916-17 should be in the hands of the committees on or before June 1, 1916.

Dr. Victor G. Bloede, the founder of the Bloede scholarship, is president of the Victor G. Bloede Company of Baltimore, Md.

Mr. William F. Hoffmann, the founder of the Hoffmann scholarship, is president of the American Oil and Supply Company of Newark, N. J.

Flotation and Cyanidation

A Symposium on the Cyanidation of Flotation Products and the Influence of Flotation on the Relative Importance of Cyanidation as a Metallurgical Process

With the extension of the flotation process to the concentration of gold and silver-bearing ores, new problems have confronted the metallurgist on the cyanidation of flotation products. The early use of flotation was confined mainly to the treatment of base-metal ores—copper, lead or zinc—in which the precious metals existed not at all or had a minor value. Now, however we find flotation displacing gravity concentration on sulphide gold and silver ores. In the treatment of some of these ores it has been customary to cyanide table concentrates, and in others, the tailings. The advent of flotation immediately raised the question of the feasibility of cyaniding these products, should they be produced by flotation instead of by conventional gravity processes. Certain difficulties seemed inherent, even before experiments were made, chief of which was the possible influence of the oil in the concentrate or tailing. Subsequent investigations confirmed some of the early ideas; and while progress has since been made, it is still evident that a large problem remains to be solved. Then, too, there was the question of the economic effect of flotation on the future use of the cyanide process; whether the position of cyanidation as the premier method of recovering gold and silver would be materially affected by the wider adoption of flotation.

We have deemed these phases of flotation to be of great importance, and have made an effort, through the medium of a questionnaire, to elicit such information as is now available. A number of the answers are presented herewith, being offered for mutual profit by engineers more or less actively engaged in the treatment of ore by the two processes. While they sound no note of finality, they are distinctly encouraging in their general tone, and indicate that success can be achieved. Following are the questions and some of the replies received thus far. We invite further discussion of the subject.

1. Are oil-flotation products—concentrates and tailings—as readily cyanided as similar products from ordinary wet concentration?

2. To what are the difficulties, if any, to be ascribed, and what are the remedies?

3. Are the difficulties likely to prove serious enough to react against cyanidation and restrict its use?

4. Is it possible that a combination of flotation plus smelting may in some cases prove more economical than cyanidation?

5. Does flotation appear to-day in any sense a competitor of cyanidation in the treatment of gold and silver ores, or will it prove a valuable accessory process?

J. M. Callow.—In a general way, I would say that as far as flotation replacing cyanidation is concerned, it looks as if we could successfully do it in two places at least, namely, at Cobalt, Ontario, and also at Goldfield, Nev. In Cobalt I am making a ½-oz. tailing on a 9-oz. silver feed, and a 250 to 300-oz. concentrate. There are a great many difficulties in cyaniding these concentrates. They do not seem to yield to cyanide in any way. Mr. Jones of the Buffalo Mines Company is conducting a number of experiments to see how best to reduce them, including treatment by chlorine gas and chloridizing roast, but with what success we do not know.

As to Goldfield, we have been operating there with a 75-ton plant for the last sixty days, and are obtaining uniform results of better than 90 per cent of the

gold, 75 per cent of the silver and all of the copper. The Goldfield people are treating these concentrates by cyanidation without any trouble after having given them a preliminary roast and an acid leach to remove the copper.

In some cases, where the smelting and freight facilities are good, I think flotation will entirely replace cyanide. In other places cyanide will be a supplemental process for the purpose of treating the concentrates from flotation. On other ores, higher cyanide recoveries can be made by using flotation to remove the interfering sulphides. This we did at the El Rayo Mine in Mexico. We found that we not only increased the recovery but reduced the cyanide consumption by giving the ore a preliminary flotation treatment. The oils used in the process evidently did not interfere with cyanidation.

Salt Lake City, Utah.

James Johnston.—You have presented an interesting lot of questions, the reply to which, from the point of view of our Cobalt ore, involves a great amount of work.

We are endeavoring to answer these same questions for our own account and without any guess work. We have installed as a unit to our low-grade mill a Callow plant of three roughers and one cleaner, and we are investigating the matter thoroughly.

In the meantime, until we finish our task, I cannot go on record as to how flotation may affect our metallurgy in this district.

Cobalt, Ont.

R. W. French.—1. We have not many data on this subject at this time, but do not anticipate any trouble in treating our flotation concentrates. The present indications are that we will not have to give flotation tailings any cyanide treatment, although this does not offer any unusual difficulty.

2. Possibly finer grinding of concentrates may be necessary, and other difficulties might develop according to the kind and quantity of oils used on the ore.

3. No.

4. Possibly in a few cases, depending on supplies and fuel, but generally not.

5. Regard flotation as an accessory process and not a competitor of cyanidation in the treatment of gold and silver ores.

Goldfield, Nev.

Philip Argall.—I must frankly state that I have had but little experience in the treatment of flotation concentrate by cyanide, as my work during the past four years has been almost entirely in the flotation of zinc sulphides.

1. Experiments made on Cripple Creek ore in 1907 showed that the float was very difficult to cyanide unless roasted, but after roasting no difficulty whatever was experienced.

2. The difficulties in that case and with some other ores tested in the laboratory were due to the oil. This condition was most easily remedied by roasting, provided very little silver was present; but roasting silver ore is fatal to good extraction by cyanidation.

4. It is my opinion that smelting the float concentrate, where gold and silver are present, is the better

method of procedure, but here again freight cuts an important figure. If a flotation plant is situated in a remote district, freight might eat up all the profits.

5. Flotation, like every new thing, is greatly overdone. At present the tendency is toward displacing cyanidation by flotation, but on the whole I do not look upon flotation as the competitor of cyanidation in the treatment of straight gold ores or medium-grade gold and silver ores, but of course every case must be studied separately.

Flotation will undoubtedly prove a valuable accessory in many cyanide plants.

Denver, Col.

Edwin Letts Oliver.—1. Flotation products ("oil" should not be used, to be strictly up to date in your terminology) are of such radically different natures that a general reply is not possible. Concentrates from silver ores are very difficult to cyanide, whereas concentrates from gold ores are frequently just as amenable to treatment as table concentrates. Flotation tailings are frequently more amenable to cyanidation than either unconcentrated tailings or tailings from tables, and I believe that flotation will be extensively adopted as a preliminary step in many cyanide plants.

2. I have never found any two authorities to agree why flotation concentrates from some ores cannot be cyanided, whereas table concentrates from the same ore can be.

3. Difficulties have proven so serious in many cases that flotation could not be adopted, although it made a splendid recovery. In cases where the plant is far removed from a smelter and where transportation is difficult, it may be more economical to cyanide the concentrate, i.e., table concentrate, even though a lower recovery be made, than to ship the flotation concentrate.

4. It is very possible that a combination of flotation plus smelting will prove more economical than cyanidation. Transportation of the concentrate in many cases will be the deciding factor. On gold ores, a combination of amalgamation and flotation may in many cases supplant cyaniding. The Chichagoff Co. of Alaska has recently installed a flotation plant to follow their amalgamation plant. They recover 80 per cent in free gold on the plates, but have never been able to make satisfactory recovery by table concentration, whereas flotation recovers better than 90 per cent of the value in the amalgamation tailing. This combination in mill treatment, we believe, has been but little discussed. I look forward to seeing plants of this kind in California, especially on the slate ores of the Mother Lode belt, where table concentration gives poor results and where table concentrate cannot be cyanided, and also where the slime tailing cannot be cyanided.

5. As yet, flotation has not been a serious competitor of cyanidation in the treatment of gold and silver ores, but it is already a valuable accessory, and we believe in time may eliminate 50 per cent of cyanide plants.

San Francisco, Cal.

Walter Neal.—I pass over Questions 1, 2 and 3 as I do not know the answer. For No. 4, I would say that on the result of tests made by myself at the Bureau of Mines Experimental Station in Salt Lake City last winter, we propose to put in a flotation plant at the El Favor mine as soon as Mexico is safe to operate in. I am sure that we can make a profit by floating and shipping the concentrate to the smelter. The main reason is that we can get no guarantee of a supply of cyanide. The price is high; but we might

stand that if we were assured of getting it when we need it, but we do not feel like starting the plant again on a cyanide basis at present. Consequently, we shall float and ship, and when the cyanide and zinc supply again becomes normal we shall decide on the merits of the case whether to continue flotation or go back to cyanidation.

For No. 5, under present conditions, flotation is most decidedly a competitor of cyanidation as above, and I believe that for some ores it will compete under normal conditions.

I believe that a combination process will be worked out, but so far as I know this is not being practised anywhere as yet. There are difficulties in the way, but flotation is a husky youngster, and it is hard to say just where its growth will stop.

Hall, Mont.

Henry E. Wood.—1. No, they are not.

2. (a) Unless the oil-enveloped particles are freed from oil they cannot be so readily influenced by cyanide solutions. To remove the oil requires a temperature that is likely to roast the minerals more or less. At any rate it adds to the expense.

(b) Flotation is likely to throw into the concentrates fine particles of copper and other minerals (such as gray copper), which if present in small proportions are generally lost in wet concentration. If saved by flotation, they cause an excess of cyanide consumption. In attempting to cyanide a certain silver ore from Montana we found that a 48 per cent extraction consumed 72 lb. of cyanide per ton, which was prohibitive. Flotation of this ore saved 98 per cent in a 4000-oz. product.

3. I think flotation opens a field for the concentration of ores not susceptible to cyanidation. I do not think flotation will restrict cyanidation. It is quite evident that the proportion of ores subject to flotation will in time yield a recovery greatly exceeding that from cyanidation, because of the greater volume of ores that are not adaptable to the latter method.

4. The combination of flotation plus smelting is not likely to compete with cyanidation. The smelting of flotation concentrates is the most serious problem before the smelter to-day on account of dust losses, etc. It will probably result in a decided advance of smelting costs for such products.

5. Naturally flotation becomes a competitor of cyanidation in some cases, but not to an alarming extent. Of course, it is a valuable accessory process, but to take care of the flotation product calls for radical changes in smelting. In due time new smelting systems will, as the result of experience, be able to solve this most important problem. It is a very serious question with the smelter now, and sooner or later that issue will be raised. It is quite likely that new lixiviation methods will enable the smelting of such products to be dispensed with.

Denver, Col.

Charles W. Merrill.—1. No.

2. Not as yet prepared to say.

3. In my judgment, no.

4. Yes, it is possible in special cases.

5. In my opinion, flotation will prove a valuable accessory process to cyaniding within the next few years.

San Francisco, Cal.

Bernard MacDonald.—1. No.

2. The difficulties are due to (a) the oil films that adhere tenaciously to the metal-bearing sulphides in the concentrates. These oil films constitute a protective covering which prevent the cyanide solution from coming freely into direct contact with the sul-

phide particles, a condition necessary for effectively dissolving out the gold and silver contained in them; and (b) the carbon contained in the oil films is in position to be immediately available to react as a precipitant on the gold and silver that may be dissolved out of the sulphides and brought into the cyanide solution. When thus precipitated, the gold and silver becomes insoluble in further contact with the cyanide solution. The commercial result is, therefore, the same as if the gold and silver had never been dissolved out of the concentrates. As a remedy for obviating these results, I suggest submitting oil flotation concentrates to a dead roast, which would drive off the carbon contained in the oil films and leave behind only an insignificant amount of ash, which would not affect unfavorably the subsequent cyanidation. The roasted concentrates would be in a porous condition, so they could be effectively and cheaply cyanided by percolation.

3. There are good and sufficient reasons for the conclusion that oil-flotation will give better commercial results than cyanidation on certain silver sulphide ores that contain small percentages of copper, manganese and antimony. In many cases such ores are now treated profitably by cyanidation, notwithstanding the comparatively low percentage extraction and the high consumption of cyanide and other chemicals used in the process. But the recent advance in the price of cyanide, zinc and other reagents used in the cyanide process will make the oil-flotation treatment a desirable alternative for these ores. It is perhaps going too far with present knowledge to say that even the single sulphide silver ore (argentite) that is now considered the most docile for cyanide treatment will eventually be preferably treated by oil-flotation, but that is possible if not probable.

However, for silicious gold and silver ores wherein the silver occurs in the haloid combinations such as the chlorides and bromides, the cyanide treatment will remain the standard method.

4. Yes. In cases where the silver occurs in more or less refractory combinations as above mentioned, and especially where it occurs associated or combined with galena, flotation plus smelting will be more economical than cyanidation, but these cases will be affected by transportation facilities.

5. Covering the answer to this question, and as a general conclusion from the answers to the previous questions, the writer's opinion is that oil-flotation will have to be reckoned with as a strong competitor of cyanidation within the limitation outlined above.

As an accessory process to cyanidation, flotation will doubtless also have a field.

Los Angeles, Cal.

Thomas B. Crowe.—1. Yes.

2. To oil coating on mineral, the remedy for which is roasting.

3. Yes, unless the oil is burned off.

4. Yes.

5. Yes, so far it has not been made an accessory process.

Victor, Col.

Charles A. Chase.—1. I have not myself tried to cyanide oil-flotation concentrates or residues, but authoritative articles in the technical press indicate that the cyanidation of these materials is unsatisfactory to date.

2. I have always assumed that the flotation reagents would be destructive of cyanide and prejudicial to good extraction.

3. I think so.

4. I think it probable.

5. It is a competitor.

I do not see any object in speaking of flotation as a competitive process. What it really does is to make metallurgy more flexible by providing a new tool. For years the practice of cyanidation has been expanded to more and more difficult ores, ores which are now found readily amenable to the simpler process. This is particularly true of the silver ores. In my own practice I found silver ores in Ouray County, Col., that could be cyanided profitably following table concentration, but flotation is far better adapted. It seems to be a case for careful study to adapt processes to the individual ore.

Denver, Col.

Charles E. Locke.—1. From personal experience we cannot say whether oil-flotation products are as readily cyanided as wet concentration products.

2. The differences, if any, can only be ascribed to the reagents used, namely, the oil and the electrolyte. Where the electrolyte is of acid character, one would naturally expect that more lime would have to be added to overcome the acidity, but it does not seem that the conditions would be any different from those which existed where concentration is carried on in acid water. The remedy, provided a remedy is found to be necessary, would apparently be complete drying, to the point of incipient roasting. As to the effect of oil in cyaniding, I do not feel that I am sufficiently versed in the chemistry of cyaniding to predict what would happen; but we all know that a reducing agent in the cyanide solution is considered to be harmful, in that it causes reprecipitation of the gold. All oils come within the class of reducing agents, and would presumably cause this effect. The remedy would appear to be the same as that for electrolyte, namely, drying.

In this connection I recall that only recently a friend of mine told me of his experience with flotation zinc concentrates. He treats these concentrates electrolytically. At first he only dried them before the electrolytic treatment, but he found that the small quantity of oil which they contained was very harmful, and he has therefore been obliged to continue the drying to the point of redness, and thus entirely burn off, or, as he expressed it "fry out the oil."

3 and 4. The answers to these questions will be given by the ledger. Where the margin of profit is small, there will certainly be instances where the extra cost of preparing the flotation concentrates for cyaniding will tend to restrict its use. Further, if a mill is favorably located regarding freight and smelting rates, there would appear to be a possibility that flotation plus smelting might be more economical than cyaniding.

5. The development of flotation is so rapid that one is kept busy every minute in keeping up with progress. It is eight months now since I traveled through the West; at that time I did not find flotation considered as a competitor of cyaniding, except that certain men, especially Mr. Charles Butters, were predicting that it would become a competitor. No instances have come to my attention as yet where flotation has come into competition with cyaniding, but there seems no reason to say that this condition will continue for all future time.

We can surely say that flotation is going to be a valuable adjunct to cyaniding. The Nipissing Mining Company, at Cobalt, reports that they are installing a working unit in their mill to treat the tailings from cyaniding, their laboratory experiments having indicated that an additional recovery may be

made by flotation on these tailings at a profit. The great advantage of cyaniding always has been that it delivers a product in the form of bullion, that is, in a very concentrated form which could be sold in the open market, and required no further treatment except, possibly, parting. The fact that flotation yields, as a rule, sulphide concentrates, which are more bulky than metal, and which require further treatment before they become marketable, is going to be a considerable handicap.

Boston, Mass.

Flotation Symposium

Joint Meeting of New York Sections of American Institute of Mining Engineers and American Electrochemical Society

A very enjoyable joint meeting, preceded by an informal dinner, was held on Friday, May 12, at The Chemists' Club, New York City, by the New York Sections of the American Institute of Mining Engineers and of the American Electrochemical Society. Both sections elected officers for the coming year, as follows:

New York Section American Institute of Mining Engineers—David H. Browne, chairman; Percy E. Barbour, vice-chairman; A. D. Beers, secretary; C. A. Bohn, treasurer.

New York Section American Electrochemical Society—Dr. Colin G. Fink, chairman; John V. N. Dorr, vice-chairman; J. Malcolm Muir, secretary-treasurer.

The subject of the evening was a symposium on the "how" and "why" of flotation. The two principal speakers were Mr. George D. Van Arsedale, consulting chemist of Phelps, Dodge & Co., who discussed the "how" of flotation, and Prof. Wilder D. Bancroft of Cornell University, who discussed the "why."

Mr. Van Arsedale defined flotation as that process of concentration which utilizes the different behavior of different kinds of particles toward the surfaces of liquids and gases and separates them, irrespective of the action of gravity. Since we have, therefore, to deal in flotation with surface phenomena, the subject is closely connected with colloids.

By means of a series of very interesting experiments shown on the screen with a projection lantern, Mr. Van Arsedale discussed, step by step, the different items which influence and determine flotation. Under what conditions will a cylindrical metallic wire float horizontally on water? Gravity acts on the wire trying to sink it, and this force is the greater the greater the specific gravity and the diameter of the wire. Experiment shows that there is a maximum diameter, for which a wire of a certain material will float, and that this maximum diameter can be calculated very closely from surface-tension formulae. This proves absolutely that surface-tension is at the bottom of the force which acts against the action of gravity and makes the wire float. What factors determine this force? First, the shape of the particle and, second, the surface angle, and the surface angle again depends on the surface film on the particle. This surface film may be either a solid (copper oxide behaves very differently from copper sulphide) or a liquid (oil) or a gas or an electrostatic charge (capillary electrometer) or a combination of these. With respect to the action of gas films it was conclusively shown by experiment that the method of producing the gas is without influence on the flotation.

On the basis of his classification Mr. Van Arsedale discussed the principal phenomena of flotation, and finally took up the discussion of flotation oils. They

have a double function as oilers (furnishing a non-wet film on the particle) and as foamers (furnishing a froth by reducing the surface tension).

The interesting suggestion was made by Mr. Van Arsedale not to add the oil as a whole as is done at present, but according to the two different functions to be fulfilled, to add first the oiler to the mill (to coat the particles) and afterwards the foamer to the flotation machine. He also suggested that petroleum may be used as oiler.

Emulsifications are detrimental to flotation. Hence any agent which tends to emulsify the oil (like tannin, saponin, glue) is detrimental to flotation, while reversely anything that counteracts emulsification (like sulphuric acid) helps flotation.

Mr. Van Arsedale concluded that we are only beginning to realize the scope of the flotation process, we may even have flotation without oil.

Mr. Van Arsedale's flotation experiments in a little glass cell thrown on the screen by means of a projection lantern were exceedingly well chosen to illustrate typical cases and succeeded very well.

Prof. Wilder D. Bancroft spoke in his characteristic felicitous and witty manner. He emphasized that in principle he was in full accord with Mr. Van Arsedale, and differed from him only in the way of looking at the problem and describing it in words. Instead of using the contact angle as the fundamental element, he uses the degree of wetting as basis. Water wets glass readily; mercury does not wet glass readily; water does not wet greasy glass. On such simple facts of experience we can base a description of flotation phenomena, and then the matter becomes really simple. We have selective wetting; alcohol will displace water on metal, etc.

If we have oil, water and a solid, we have three cases: the solid is entirely wetted by water, or it is entirely wetted by oil, or it is simultaneously wetted by oil and water. In flotation of a sulphide ore with a silicic gangue, the latter stays entirely in the water phase, while the sulphide goes into the "interphase" or into the oil. But this flotation process is not a special phenomenon depending on oil, as an exactly analogous distribution between the different phases can be obtained with a great many chemical materials.

Professor Bancroft explained why alkaline solutions are less satisfactory for flotation (adsorption of hydroxyl) and acid improves flotation. Flotation differs at different temperatures, because selective wetting depends on the temperature. What is wanted in flotation is an oil froth, not a water froth. Soap, etc., produces water froth, and is detrimental. No pure oil is a foamer; a foamer always requires colloidal matter or suspensions. This suggests the possibility of the synthesis of foamers.

When very little oil is used it is possible that in addition to oil-water flotation the air may come in, and this may be an important matter; this is open to experimental investigation.

Prof. R. H. Richards of the Massachusetts Institute of Technology, who presided during the technical session, opened the discussion with a reference to the Anaconda Copper Company, which had installed \$300,000 worth of round tables which produced a very important saving, but were thrown out when flotation came in. He also told of another case in which flotation saved all the fine stuff and Wilfley tables the coarse matter.

After some further discussion in which Messrs. Free, Reed, Baskerville, Megraw and Bancroft participated, the meeting was closed by Dr. C. G. Fink, chairman of the New York Section of the American Electrochemical Society. The attendance was not far below 300.

Cost-Accounting in the Construction and Operation of a Copper Smelter

Construction Accounts for a Copper Smelter

BY ERNEST EDGAR THUM, E.M.*

The following list of accounts is believed to be adequate to cover practically all the usual construction for a copper smelter. Accounts for concentrator and refinery have been omitted, but it is patent how the list could be extended to cover such additional departments.

GENERAL CONSTRUCTION EXPENSE, ACCOUNTS C 0 TO C 9

Camp and Commissary	C 0
Railroad Spurs	C 1
Fagon Roads	C 2
Electric Lines	C 3
Pipe Lines	C 4
General Clean Up	C 5
Watchmen	C 6
Central Concrete Mixing Plant	C 7
Construction Machinery	C 8
Misc. Small Tools and Equipment	C 9

STORAGE-BINS CONSTRUCTION ACCOUNTS; ACCOUNTS C 10 TO C 19

Ore Bedding Plant	C 10
Thawing Shed	C 11
Sampling Mill Bins	C 12
Blast Furnace Bins	C 13
Roaster Bins	C 14
Reverberatory Bins	C 15
Converter Bins	C 16
Flue Dust Bins	C 17
Boiler House Bins	C 18
.....	C 19

SAMPLING-MILL CONSTRUCTION ACCOUNTS; ACCOUNTS C 20 TO C 29

Building	C 20
Crushing Machinery	C 21
Screens	C 22
Samplers	C 23
Spouting	C 24
Elevators	C 25
Conveyors	C 26
General Power Transmission	C 27
Hucking Room	C 28
Misc. Small Tools and Equipment	C 29

BLAST-FURNACE PLANT CONSTRUCTION ACCOUNTS; ACCOUNTS C 30 TO C 39

Building	C 30
Furnaces	C 31
Flue Connections	C 32
Dust Chamber	C 33
Water Tank	C 34
Elevators	C 35
Launders and Sluices	C 36
.....	C 37
.....	C 38
Misc. Small Tools and Equipment	C 39

ROASTING-PLANT CONSTRUCTION ACCOUNTS; ACCOUNTS C 40 TO C 49

Building	C 40
Furnaces	C 41
Flue Connections	C 42
Dust Chamber	C 43
Water Tank	C 44
Elevators	C 45
Conveyors	C 46
General Power Transmission	C 47
.....	C 48
Misc. Small Tools and Equipment	C 49

REVERBERATORY-PLANT CONSTRUCTION ACCOUNTS; ACCOUNTS C 50 TO C 59

Building	C 50
Furnaces	C 51
Flue Connections	C 52
Dust Chamber	C 53
Waste Heat Boilers	C 54
Fuel Plant	C 55
Launders and Sluices	C 56
.....	C 57
.....	C 58
Misc. Small Tools and Equipment	C 59

CONVERTER-PLANT CONSTRUCTION ACCOUNTS; ACCOUNTS C 60 TO C 69

Building	C 60
Converters	C 61
Flue Connections and Hoods	C 62
Dust Chamber	C 63
.....	C 64
Cranes	C 65
Slag Casting Machine	C 66
Copper Refining Furnace	C 67
Copper Casting Machine	C 68
Misc. Small Tools and Equipment	C 69

MAIN FLUE AND STACK CONSTRUCTION ACCOUNTS; ACCOUNTS C 70 TO C 79

Fume Plant Building	C 70
Fume Plant Equipment	C 71
Connecting Flues	C 72
General Dust Chamber	C 73
Main Stack	C 74
.....	C 75
.....	C 76
.....	C 77
.....	C 78
Misc. Small Tools and Equipment	C 79

BOILER-HOUSE CONSTRUCTION ACCOUNTS; ACCOUNTS C 80 TO C 89

Building	C 80
Boilers	C 81
Flue	C 82
Smoke Stack	C 83
Live Steam System	C 84
Coal-Handling System	C 85
Ash-Handling System	C 86
Condensing System	C 87
Feed Pumps	C 88
Misc. Small Tools and Equipment	C 89

POWER-HOUSE CONSTRUCTION ACCOUNTS; ACCOUNTS C 90 TO C 99

Building	C 90
Water Supply Pumps	C 91
High-Pressure Pumps	C 92
Blast-Furnace Blowers	C 93
Converter Blowing-Engines	C 94
90-Lb. Air Compressors	C 95
Direct-Current Generators	C 96
Alternating-Current Generators	C 97
Substation and Switchboard	C 98
Misc. Small Tools and Equipment	C 99

TRANSMISSION-LINE CONSTRUCTION ACCOUNTS; ACCOUNTS C 100 TO C 109

General Water Supply Tanks	C 100
Water Supply Lines	C 101
High-Pressure Mains	C 102
Blast-Furnace Air Main	C 103
Converter Air Main	C 104
90-Lb. Air Lines	C 105
Electric Power Lines	C 106
Electric Lighting Lines	C 107
Steam Power Lines	C 108
Steam Heating Lines	C 109

YARDS AND RAILROAD TRACKS CONSTRUCTION ACCOUNTS; ACCOUNTS C 110 TO C 119

Interconnecting System	C 110
Storage Bins Trackage	C 111
Slag Tracks	C 112
Blast-Furnace Charge Tracks	C 113
Roaster Charge Tracks	C 114
Reverberatory Charge Tracks	C 115
Converter Charge Tracks	C 116
Flue-Dust Tracks	C 117
Copper Tracks	C 118
Misc. Small Tools and Equipment	C 119

SHOPS CONSTRUCTION ACCOUNTS; ACCOUNTS C 120 TO C 129

Machine Shop	C 120
Smelter Mechanics Shop	C 121
Boiler Shop	C 122
Blacksmith Shop	C 123
Carpenter Shop	C 124
Pipe Shop	C 125
Electric Shop	C 126
Bricklayers and Mason Shop	C 127
Locomotive and Car-Repair Shop	C 128
Crane-Repair Shop	C 129

MINOR BUILDINGS CONSTRUCTION ACCOUNTS; ACCOUNTS C 130 TO C 139

Office Building	C 130
Laboratory	C 131
Change House	C 132
Warehouse	C 133
Oil House	C 134
Powder House	C 135
Lime House	C 136
Outside Toilets	C 137
Watchmen Shanties	C 138
Scale Houses	C 139

MISCELLANEOUS CONSTRUCTION ACCOUNTS; ACCOUNTS C 140 TO C 149

General Yard Grading	C 140
General Yard Lighting	C 141
Main Sewer	C 142
Fences	C 143
Fire Department Equipment	C 144
Water Development	C 145
Telephone System	C 146
Weather Bureau	C 147
.....	C 148
.....	C 149

The system underlying this arrangement is obvious; briefly to group together the different accounts necessary for a department or similar class of structures, each account number possessing the same digit in the tens place. Thus all accounts in the sixties refer to converter plant. The unit digits have been arranged as far as possible to have a similar significance; e.g., 3 for "dust chamber," 9 for "operating tools." Account 69, therefore, will represent operating tools for the con-

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verter department, 119 the same for yards and railroad tracks.

Furthermore, all accounts for buildings (having 0 for their unit digit) can be subdivided in exactly the

	20	30	40
same manner; in this way, C —, C —, C —, etc., will	6	6	6

all represent, say, wiring and lighting for the building whose account is C 20, C 30 or C 40.

A quite full list of accounts covering a large departmental building is given below, and will be adequate for all mill-building construction without material change.

1. Excavation and Backfilling.
2. Foundation.
3. Floors and Paving.
4. Steelwork and Erection.
5. Brickwork.
6. Wiring and Lighting.
7. Steam Piping.
8. Water Piping.
9. Air Piping.
10. Sewer Connections.
11. Ventilators.
17. Siding and Partitions.
18. Doors.
19. Windows.
20. Roofing.
21. Walks and Stairways.
22. Sprinkler System.
23. Departmental Office and Furniture.
24. Tool Room (excluding tools).
25. Toilets.

Quite a number of these sub-accounts need not appear in the minor buildings. In such case it is desirable merely to leave them blank without disturbing the pre-arranged list, so that sub-number 22, for instance, shall always represent sprinkler system. Shop accounts C 120 to C 129 will obviously require slight extensions to cover cost and installation of machine tools and motive power. Close adherence to this scheme will insure a practically self-indexing system, capable of indefinite expansion.

In a similar manner, accounts for furnace construction can be subdivided as follows:

1. Excavation and Backfilling.
2. Foundation.
3. Platforms.
4. Steelwork and Erection.
5. Brickwork.
6. Electrical Equipment.
7. Steam Piping.
8. Water Piping.
9. Air Piping.
10. Sewer Connections.
11. Hoods and Shields.
12. Feed-Bins and Gates.
13. Jib Cranes.

Observe that the sub-numbers from 1 to 11 have the same significance (in most cases the same wording) as the building sub-numbers, while numbers 12 and 13 are accounts peculiar to furnace construction. This list can evidently apply almost without change to all classes of machinery.

Accounts C 110 to C 119 require separate treatment. A list of sub-numbers for track construction, following that of the Interstate Commerce Commission, is as follows:

- T 4. Grading.
- T 5. Ballast.
- T 6. Ties.
- T 7. Rails, Track Fastenings and Other Track Material.
- T 8. Frogs, Switches and Special Work.
- T 9. Rail Bonding and Insulating Joints.
- T 10. Retaining Walls.
- T 11. Track Laying and Surfacing.
- T 14. Trestles.
- T 15. Culverts.
- T 16. Grade Crossings, Fences, Cattle Guards, Signs.
- T 17. Interlocking and Signal Apparatus.
- T 19. Poles and Fixtures.
- T 20. Underground Conduits.
- T 21. Trolley Wires.
- T 22. Third Rail.
- T 23. Track Scales.
- T 25. Cars.
- T 26. Locomotives.
- T 29. Miscellaneous Equipment.

Since the correspondence between significance and numeral is lost in this subdivision, the sub-numbers are

prefixed by the letter "T," in order to immediately

arrest attention. Thus, in account C —, the "T" will

divert the mind from "wiring and lighting," its usual meaning, to the special meaning "ties" for the blast-furnace charge track.

Instructions for Employees

Each engineer, foreman and clerk who has to aid in the distribution of charges will need to refer constantly to a complete list of the construction accounts. For this reason it will be necessary to prepare a number of books for these men to carry about with them. A quantity of leaves for the standard loose-leaf notebooks should be printed listing the different general sub-numbers. The name and number of the account can be typed at the top of the leaf, any superfluous sub-numbers ruled out or extras inserted. The sheet is then dated, and inserted into a book which will contain the complete classification. Any additions or alterations to the list can easily be made by simply inserting corrected sheets in the appropriate places. Warehouse orders, shop job orders, teaming orders and a supply of blank memorandum sheets will complete the book.

The drawing room can render invaluable service toward insuring correct segregation of expense by placing on each drawing the proper account number covering the work drawn up, as far as possible confining the subject matter of one detail drawing to one sub-number. On general drawings the scope of each account appearing should be carefully differentiated; this drawing then is immediately useful as an index for that particular construction. In addition to this help, however, it will be desirable to preface the account book by brief general rules as to the scope and meaning of the various numbers. For instance, it should be pointed out that excavation for a building will include grading of the site, digging pits for building column piers, trenches for retaining-wall footings, finishing the grade for floors or tracks inside the building. Trenches for pipe lines, however, should be charged to the piping in question. Pipe accounts end at the building lines; outside this their construction is chargeable to "transmission lines," accounts C 100 to C 109. If a foreman needs a shovel for a laborer working at the converter tool room, he should charge it to "construction expense," account C 9, "small tools and equipment," and not to

account C —, "excavating for converter building," nor to
 1
 60
 account C —, "converter tool room." A stock of shovels
 24

for converter operation will be charged to account C 69, "converter small tools."

Note, however, that a construction foreman would have no right to make a charge to this account, and there is little danger of such a charge going through, if the organization described is employed. If it is within the authority of a foreman to requisition the warehouse for small tools for the use of his gang, and he should make an erroneous charge for them, it would be noted and corrected by the timekeeper later in the day when he inspected the cards in the supply room. Each foreman's authority for making charges should be limited strictly to the few accounts upon which he is working. This will still the temptation to charge labor or material to another man's job in order that his own may appear with a low cost. But any charge which may slip through in error is practically certain to be caught before long by the timekeeper, who, devoting his whole

attention to this matter, will become quite expert in the proper segregation of charges.

We might expand at some length on the necessary qualifications for a good timekeeper to handle the duties outlined above. Suffice it to say that I have found that a reliable level-man is the best. He already knows the elements of construction and has the habit of accuracy permanently instilled. The rest is child's play. The extra salary he will require will be repaid many times over.

Comparison of Literal and Numeral Systems of Notation

Many of the modern authors on accounting favor a scheme which will denote the different accounts, not by numerals but by letters, using the initials of the wording wherever possible. Under such a scheme S would denote "shop," SM "machine shop." These mnemonic aids are rapidly exhausted, however, and we will find SMA meaning "excavation for the machine shop," SMB "foundation," and so on. It seems that 1 is as good a symbol for excavation as A; the added advantage is that the number series is not limited to twenty-six members. The system expounded here reserves letters for sub-accounts under operation, and numbers for sub-accounts under construction, thus affording an automatic segregation of these two important classes of charges.

The subdivision of main estimates as given may be regarded by the auditor as much too minute for the needs of the general accounts. On the other hand he may desire to get more detail in some accounts, such as those covering furnaces. Should different types of roasters be constructed, it would be necessary to distinguish between them in all their parts. This can easily be done by numbering the furnace batteries, and then denoting, say, "brick work in battery No. 2" by

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account C—No. 2.

5

Even the above fairly detailed distribution will be inadequate for the purposes of the cost-clerk. He therefore will consult with the chief engineer and determine what details will be most illuminative and useful, and will instruct the timekeepers and estimators how to collect the data in order that the desired segregation may be obtained. Under "steelwork and erection" the following list may be desired:

- Sorting in the yard.
- Hauling to the erection gangs.
- Assembling bents on the ground to be erected complete.
- Erecting steel by locomotive crane.
- by derrick car.
- by traveler.
- by gin poles.
- by derricks.
- by hand lines.
- Constructing and maintaining traveler.
- Moving traveler forward.
- Moving gin poles.
- Moving derricks.
- Erecting these various types of tools.
- Dismantling them.
- Erecting false work.
- Dismantling false work.
- Riveting gang scaffolds.
- Riveting.
- Cutting out and redriving bad rivets.
- Bolting floor plates.

Timekeepers and estimators in particular will be re-

50

quired to see that each charge made to C—will bear a

4

tersely worded description which definitely refers it to some item in this list. Doubtful cases should be referred to the cost-clerk for decision, who may extend the list to cover unexpected developments.

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The Grading Industries

BY EDWARD S. WIARD

(Continued from page 533)

Description of Industrial Operations Employing Grading

Abrasive Grains and Products

The term "abrasives" includes natural and artificial products. The principal natural abrasives are emery, corundum and various forms of silica and silicates. The artificial abrasives are carborundum, alundum, etc.

I will leave the preparation of abrasive papers and grits to the end of this section, dealing first with emery, which, in the popular mind, is the abrasive par excellence. Emery deposits occur in the whole length of the Appalachian range associated with metamorphosed and igneous rocks, principally schists, but the annual production is only about 1000 tons. The most famous deposits were at Chester, Mass. The color of emery is black or grayish-black, due to the intimate presence of hematite. The abrasive is consequently an intimate mixture of aluminium and iron oxides, the proportion of the latter varying in percentage.

Much oriental emery is graded in the United States, some of the old mills near Chester, idle on domestic ore, being employed for this purpose. There are also grading plants at Perth Amboy, N. J.; Easton, Pa., and North Grafton, Mass. All the emery graded in the United States comes from the Grecian Archipelago and Turkey. In 1914 some 13,000 tons was imported, having a value of \$500,000. The emery comes over principally as ship ballast. The Grecian government practically has a monopoly of the emery exported from the Archipelago by taxing grades inferior to its own deposits at Naxos, where the emery occurs very pure and massive.

The methods of grading emery do not differ from those to be described later on under sandpaper and artificial abrasives. The useful property of emery as an abrasive, as with corundum, and particularly when made up into wheels, depends upon its ability to crumble under pressure, thus always presenting fresh cutting surfaces. Emery and corundum which is tough and grinds to rounded grains is worthless, particularly in wheels, where with use it will acquire a glassy surface. Owing to its lower price, emery is still able to maintain a hold in many fields, particularly in those employing abrasive cloth.

No corundum has been mined in the United States since 1906. Practically all this material comes from mines in the vicinity of Craigmont, Ontario. The corundum occurs in syenite, and in crystals up to 1½ in. in length. The percentage varies from 5 to 15. The ore is mined by open cuts, crushed with rolls and crushers, and cleaned by wet concentration methods, using jigs and tables. The principal difficulty is in getting rid of the feldspar, which has a gravity 2.5 to 2.8, that of corundum being 3.9 to 4.2. But one company controls the field at present, The Manufacturers Corundum Company. During 1912 it shipped 1900 tons of graded product valued at \$239,000, and worth 6¾ cents per pound. Of late years the production has fallen off.

Quartz and Garnet

Quartz is used for sandpapers in the form of vein quartz and quartzite, but the latter is not so good for abrasive purposes as the former, for the grains are apt to be rounded when unlocked by crushing. Massive quartzite, however, does not offer this difficulty. The bulk of the quartz for abrasive purposes comes from

large pegmatitic quartz veins, and on this account the mining of the quartz often goes on with feldspar mining. So-called flint papers are merely trade names, for the expense of flint pebbles as an abrasive would be prohibitive. Flint would, however, make an excellent abrasive, for its fracture is deeply conchoidal and leaves a sharp, glassy cutting edge. The cheapest grade of imported flint pebbles costs as much as \$8 per ton in the form of ground quartz. The unground quartz is worth as little as \$1.65 per ton at the quarries.

The mining of abrasive garnet for sandpapers, owing primarily to the superior hardness of the material, is an industry which has been slowly increasing in production from year to year. In 1914 the production was 4000 tons. The mining of this material is confined to the States of New York, New Hampshire and North Carolina.

At one time garnet grains found application in the shoe industry, but its use has been supplanted by harder abrasives. For finishing hardwood, garnet paper does not break down and fill the wood like flint paper, and less time is lost in recovering the finishing rolls than with the latter.

The most valuable form of garnet is almandite, which has a superior hardness to the ordinary varieties, whose range is from 6.5 to 7.5. The garnet of this variety from the Adirondack region has a hardness from 7.5 to 8. It occurs in lenses of amphibolite in acidic granite, in crystals ranging in diameter from 1 in. to over a foot.

In working the rock it is broken down by ordinary quarry methods of picking or blasting. The garnet is recovered by hand-picking or by mechanical methods. When mechanical methods are employed the problem has been to separate the garnet from the hornblende, the latter having a specific gravity ranging from 2.9 to 3.4, while the garnet ranges from 3.15 to 4.3. In the Adirondack region, particularly at 13th Lake, Warren County, and Gore Mountain and Garnet Peak, there is usually a well-defined cleavage set up in the crystals, which are of a distorted dodecahedral form. The cleavage is usually parallel to one of the dodecahedral faces, and this gives a good surface for attachment to the paper as well as good cutting edges. The ordinary cleavage of garnet is subconchoidal. Garnet also occurs in New Hampshire, one notable locality being in Merrimac County. About 40 to 50 per cent of the rock is garnet, the associated minerals being quartz, feldspar and biotite. The garnet crystals are small and contain included quartz and biotite, necessitating fine crushing. The garnet is separated from the impurities by a Sutton, Steele & Steele dry table. In preparation for the tables the material is crushed and screened to four sizes, material finer than 0.36 mm. diameter being rejected. The coarsest grain treated does not exceed 2 mm. in diameter.

Artificial Abrasives

The first and greatest of the artificial abrasives is carborundum, or the carbide of silicon, details of the manufacture of which have appeared so often in the technical press that the brief description which would be possible here can be omitted. The same reflection would apply to a description of alundum, the artificial oxide of aluminium. Crushed steel is much used in the stone-finishing trades. In manufacture, high-grade crucible steel is heated nearly white hot and quenched in cold water. The fragments from the bath are then gathered up and crushed, yielding on grading particles varying from the finest powder to 6-mesh pieces. The material is crushed in stamps and a roughing grading is given by rotary screens and the finishing grading by

flat screens. As in grading other abrasives silk cloth is used on the fine sizes in preference to metal cloth.

Following the grading operations, the various grades of particles are tempered: the 6 to 60-mesh size is heated to 450 deg. and quenched at a straw color, while diamond-crushed steel, 60 to 200-mesh, is heated to higher temperatures. The same firm manufacturing the steel products also prepares chilled cast-iron shot for similar uses. The products are recommended by the manufacturers for polishing, sawing and grinding of granite, marble, stone, onyx, brick, glass, etc. In ordinary stone-polishing and grinding operations, the desired size of abrasive, depending on whether a polishing or grinding effect is wanted, is fed through the center of the gyratory grinding wheels, and spreads itself between the grinding surface and the piece being finished. Wheels 12 to 13 ft. in diameter are used for stone; 6 to 7 ft. in diameter for brick; 30 in. for bevelling glass.

Metal and Silk Screens Commonly Used

In grading the hard abrasives the almost universal method is by screening down to the neighborhood of 200-mesh sizes. Flat screens are preferred in most grading establishments, although in one in which I visited revolving screens were employed. Silk cloth is preferred below 30-mesh size, largely because it does not blind so easily, and also because it is cheaper. The first cost is cheaper on the square-foot basis, and the relative wear, while in favor of the metal screens, probably does not show much if any disparity on ordinary abrasives when the greater cheapness of the silk cloths is considered. In addition to blinding more readily than the silk cloth, the metal screen is more difficult to free on becoming blind.

In most of the grading establishments the flat screens are strung one beyond the other. The following description will serve for the operations by this arrangement. The abrasive material is crushed to the neighborhood of 14-mesh, then fed to a splitting box with two screens, the upper one of which is 14-mesh and the lower 54-mesh. The oversize of the 14-mesh screen goes to waste, as it contains too much foreign matter. The undersize of the 14-mesh screen drops onto the 54-mesh screen and makes over and under sizes. The oversize of the 54 goes to a battery of eight screens arranged one ahead of the other, the coarsest grade being taken off the first and successively finer off the lower ones. The undersize of the 54-mesh screens also goes to eight screens, making in the same way eight grades. The screens rest on flat irons at the side, have a slope less than 10 deg. and stroke of about an inch. The number of shakes per minute is approximately 200. Motion is given to the screens by ordinary jig eccentrics. The frames are wood and the space for the individual screen is about 18 by 40 in. For sizes above 30-mesh, wire cloth is used and silk below 30-mesh.

The various undersizes are conveyed to the screens next below those from which they originate along flat wooden bottoms parallel to the surface of the screen cloth. The striking feature of the grading in most abrasive factories lies in the very light loading; on the lower screens particularly one has to look closely to see any of the grains passing along. The oversize grains advance by bounds, and most certainly the work done is no better than would obtain with less speed or greater loading. The only advantage of this mode of operating that occurs to me is the possibly greater life of the screen cloth. There surely can be no screening effect while the particles are in the air on a bound forward. In the particular establishment under consideration the load on a single battery of screens cannot exceed 3 tons

per day of eight hours, and the load per square foot of screen surface does not exceed 2 tons per day of twenty-four hours.

At the Armour & Co. sandpaper factory a battery of shaking screens is used, one being superimposed above the other, the top screen terminating at a point farther along the discharge than the lower ones, with the terminals of the others successively less advanced. This arrangement is very compact and provides room for a series of parallel discharge spouts for the oversizes at the end of the machine. It has the possible disadvantage that some of the undersizes may reach the screen next below at a point near the discharge, and the wear on the screens may be greater than the arrangement which has been described in detail, owing to impact from the material falling from one screen to the other. The screens are inclined and are shaken, and also given a bump at each stroke, which provides a sharp differential and aids in clearing the apertures of lodged grains. The batteries are said to occupy a floor space of but 20 in. by 48 in., and the work of the machine, when fed at the proper rate, is said to repeat within 5 per cent and to be 98 per cent accurate as shown by hand-screen test.¹

Where silk cloth is used on the screens it should not be subjected to sudden changes of temperature, otherwise it is apt to tear.

At most of the plants grading quartz for sandpaper some means must be provided for regulating the proportions of the different sizes, the demand for which varies from time to time. At one of the plants visited this was done by first crushing the rock to a size capable of being nipped by medium sizes of rolls. A battery of the latter were provided, set for different sizes, and the manufacturers were consequently able to route as much or little to any particular roll as they pleased, and thus control the output to meet any extraordinary demand for a particular size.

The medium grits in the form of sandpapers which are in greatest demand are those from 40 to 84-mesh. The sizes of sandpapers are shown in Table I. Screens

TABLE I—SAND PAPER SIZES

Size	Mesh
4	on 20
3½	on 24
3	on 30
2½	on 36
2	on 40
1½	on 52
1	on 66
¾	on 84
0	on 108
00	on 130
000	on 147
0000	on 164
5/0	on 200
6/0	on 240
7/0	on 240
8/0	on 240

Variations in the thread

are universally employed for preparing the gradings, and have the merit that unless there is a hole in them there will be a rigid limiting of the upper sizes, though there may be, and often are, grades smaller than the lower size. It is claimed that oversize grains are very harmful in any particular grading, and this is more in evidence as the abrasive becomes harder. The trade, however, judges the grading by the eye; that is, if all the grains of a size appear fairly uniform, the work is accepted as good. In this connection it is interesting to note that the firms who sell their products in the form of cloth and paper are not always so careful with their grading as those who, in addition, sell the different gradings loose. Where there is too much undersize in the grading difficulty is encountered in making it adhere firmly to cloth and paper.

In addition to the sizes given in the tabulation, which are standard for all abrasives, finer sizes are produced in the following manner. At the Carborundum company's plant abrasives finer than 220-mesh are led to four conical settling tanks of 8, 18, 24 and 30-mesh top diameter, where the material settles in water, producing grades known as F, FF, FFF, and FFFF, according to the fineness, these grades being successively finer. Following this operation, the overflow of the last conical tank passes to liquor barrels, where it is allowed to settle for one minute, making the 1M grade. The material which has failed to settle is then siphoned into a second barrel and allowed to settle for four minutes, making the 4M grade. There is also an 8M and a 15M grade produced in the same way and by successive siphonings and settlements.

Abrasive Papers and Wheels

Abrasive grits are used in the free state attached to paper and cloth and in the form of wheels. In the manufacture of paper and cloth the fabrics are first sized and then rolled to remove creases. They are then hung on frames to dry, the frames being arranged so that they can be moved mechanically toward the gluing and sanding machines. The endless length of paper is supported on rolls, which form the top of the drying frame. Near the sanding machine the frame opens out and the paper is sprayed with steam. The paper or cloth then passes around rollers into a glue mixture, and thence under a shaking feeder, which sprinkles the proper size of grit upon the paper. From the sanding device the paper again passes to drying frames. After drying it may be made up into rolls or cut into sheets. At one establishment the grit is blown onto the paper, which is supposed to give it a better hold and at the same time present a better cutting surface.

In the manufacture of wheels a number of types are recognized, the principal one being the vitrified wheel. The chemical wheel is bonded with silicate of soda and some drying material, after which it is subjected to an oven heat for twenty-four hours. Other materials used for bond are shellac, linseed oil and rubber, the last yielding elastic wheels, and all being useful materials where very thin wheels are required. Vulcanite is also used as a bond and makes a very hard strong wheel, suitable for thin shapes where hardness and strength are required. The most common form of wheel is the vitrified wheel. In the manufacture various bonds are used, a suitable one for the purpose being a mixture of one part of ball clay with one part of feldspar, four parts of this mixture being used for each pound of abrasive grains. The hardness of the wheel is obtained by varying the composition of the bonding mixture. The wheels are molded wet, and when sufficiently dry to handle are trimmed and dressed to size and are then further dried. They are then burned in a kiln, the temperature being raised slowly, and the finishing temperature of 3000 deg. Fahr. is continued for several days. Several days again are required for lowering the temperature of the kiln. The different scales of hardness are shown in Table II.

TABLE II—SCALE OF HARDNESS OF ABRASIVE WHEELS

E—Soft	L	S
F	M—Medium	T
G	N	U—Hard
H	O	V
I—Medium Soft	P	W
J	Q—Medium Hard	X
K	R	Y and Z—Very Hard

Elastic Wheels are graded as follows:—1, 1½, 2, 2½, 3, 4, 5, 6, and 7. Grade 1 is the softest and grade 7 the hardest. Vulcanite Wheels are furnished where extremely hard grades of very thin wheels are desired, particularly for operations requiring the wheel being run at excessive speeds and subjected to rough treatment.

¹U. S. patent 1,011,196, Dec. 12, 1911, granted to Charles H. Hersey.

The grits for wheels are of two kinds—the aluminous grits, emery, corundum, and the artificial oxides of aluminium, alundum, aloxite, etc., and carborundum. The aluminous grits are especially suited for grinding materials with a high tensile strength, and carborundum for materials with low tensile strength. The size grit to be used and the kind are indicated in Table III, published by the Norton company. Soft wheels are used on hard materials like hardened steel. On mild steel harder grades can be used. The area of surface to be ground in contact with the wheel is of the utmost

importance in determining grade. A strongly bonded wheel must be used if it is a point contact like grinding a ball. If there is a broad contact softer grades must be used. Where there is much vibration harder wheels must be used than would be necessary if it were absent.

Miscellaneous Graded Materials

Asbestos

Over 80 per cent of this material comes from Canada, the production of other countries being unimportant. The asbestos mines of Canada are located in the eastern townships of the Province of Quebec. The most productive localities are at Thetford, Black Lake and Danville. The asbestos mined is the long-fibered variety or chrysotile. The best of it is obtained from hand-sorting, and represents fiber over an inch in length suitable for spinning.

In the milling of the quarried material, which cannot be separated by hand, the rock, after crushing, is subjected to a fiberizing operation; that is, one tending to fluff it, and this is followed by air separation to lift the fiberized asbestos, and by screens to remove the impurities. The production and value of sorted and mill products for 1913 is shown in Table IV, taken from Mineral

TABLE IV—OUTPUT, SALES, AND STOCKS OF CANADIAN ASBESTOS IN 1913, IN SHORT TONS

	OUTPUT		SALES		STOCK ON HAND DEC. 31		
	Quantity	Quantity	Value	Price per Ton	Quantity	Value	Price per Ton
Crude No. 1	2,015.4	1,853.3	\$31,200	\$286.62	880.5	\$247,877	\$281.52
Crude No. 2	3,010	3,807	457,962	120.29	1,522	178,789	117.49
Millstock No. 1	23,444	26,198	1,229,908	46.95	6,755	350,165	51.84
Millstock No. 2	58,592	60,164	1,201,215	19.97	4,809	108,285	22.52
Millstock No. 3	45,563	44,929	410,624	9.14	6,820	54,604	8.01
Total asbestos	132,564	136,951.3	3,530,909	27.97	20,786.5	939,720	45.21
Asbestos	.....	24,135	19,016	.79	.....	.....	.....

Industry. The asbestic product at the bottom of the table is the finest in size and has associated with it much impurity. The rock is crushed by rotary beater crushers.

Barytes

This substance is obtained from the mineral "heavy spar" by grinding the cleaned and sorted material, bleaching it by boiling in acid until the iron and other staining constituents are removed, washing with distilled water, grinding again in buhr mills to the requisite fineness, and grading by elutriation in water. The commercial grades of the mineral carry from 95 to 98 per cent of barium sulphate and 1 to 3 per cent silica. Crude barytes sells for \$3 to \$4 per ton. The principal producers in the United States are located in Missouri. Refined barytes sells for about \$13 per ton. The annual production of crude barytes is about 40,000 tons. Beyond its use as an adulterant and filler for giving weight, barytes has an important use in the manufacture of lithopone, a white pigment of zinc sulphide and barytes. For white rubber goods barytes is used either direct or in the form of lithopone.

Borax

The principal deposits of the world's supply of borax are found in the Death Valley district, Inyo County, California. Borax was first obtained from natural waters, from which it was extracted by evaporation. In California the first discovery of this type was made by Dr. John A. Veatch in 1859 at Clear Lake, Lake County, about 80 miles due north of San Francisco. The lake water contained about 7.63 per cent salts, of which over 5 per cent was boric acid. In Europe the principal source of borax and boric acid is the condensed

TABLE III—SELECTION OF GRADES

Class of Work	ALUNDUM		CRYSTOLON	
	Grain	Grade	Grain	Grade
Aluminum castings	36 to 46	3 to 4 Elas	20 to 24	P to R
Brass or bronze castings (large)			20 to 24	O to R
Brass or bronze castings (small)			24 to 36	P to R
Brick, fired			16 to 20	O to Q
Brick, pressed			16 to 20	O to P
Car wheels, cast iron			16 to 24	P to R
Car wheels, chilled	20	Q	16 to 24	O to Q
Cast iron, cylindrical	24 comb.	J to K	30 to 46	1 to L
Cast iron, surfacing	16 to 46	H to K	16 to 30	1 to L
Cast iron (small) castings	24 to 30	P to R	20 to 30	O to S
Cast iron (large) castings	16 to 20	Q to R	16 to 24	Q to S
Chilled iron castings	20 to 30	P to U	20 to 30	O to R
Dies, chilled iron			20 to 30	O to Q
Dies, steel	36 to 60	J to L		
Drop forgings	20 to 30	P to R		
Hammers, cast steel	30	P to Q		
Hollowware, inside grinding				O
Hollowware, thin edges			24	U
Internal grinding of automobile cylinders (cast iron)			36 to 60	1 to L
Internal grinding, hardened steel	46 to 60	J to M		
Knives (paper), automatic grinding	36 to 46	J to K		
Knives (planer), automatic grinding	30 to 46	J to K		
Knives, leather shaving	60	N to O		
Knives, leather splitting	24 to 30	1 to 2 Elas		
Knives, moulding bits, etc.	46 to 60	3 Elas		
Knives (planing mill), hand grinding	46 to 60	J to M		
Knives, shear and shear blades	30 to 60	J to M		
Knives, shoe	60	M		
Lathe centers	46 to 120	J to M		
Lathe and planer tools	20 to 24	P to S		
Machine shop use, general	20 to 36	O to P		
Malleable iron castings (large)	14 to 20	P to U	16 to 20	R to S
Malleable iron castings (small)	20 to 30	P to R	20 to 30	Q to S
Marble, finishing	180 to 200	1		
Marble, roughing			16 to 46	J to M
Marble, coping			14 to 24	5 to 7 Elas
Marble, moulding			36 to 46	L to M
Milling cutters, automatic or semi-auto, grinding	46 to 60	1 to M		
Milling cutters, hand grinding	46 to 60	J to M		
Nickel castings	20 to 24	P to Q	20 to 24	R to U
Pearl grinding, roughing			30 to 50	P to R
Pearl grinding, finishing			100 to 150	M to P
Plow bodies (cast iron), surfacing			24	R
Plows (steel), jointing	20 to 24	R to S	20 to 30	Q to S
Plow points (chilled iron), surfacing			36 to 50	O to R
Plows (steel), surfacing	16 to 24	Q to S	30 to 36	K to L
Porcelain, roughing			24 to 30	R to S
Pulleys (c. l.), surfacing faces of				
Radiators (cast iron), edges of	46 to 120	H to O		
Razors, grinding, concaving				
Reamers, taps, milling cutters, etc., hand grinding	46 to 60	K to O		
Reamers, taps, milling cutters, etc., special mach.	46 to 60	J to M		
Rolls (cast iron), wet	24 to 36	J to M	24 to 46	J to M
Rolls (chilled iron), finishing	70	1½ to 2 Elas.	70 to 80	1½ to 2 Elas.
Rolls (chilled iron), roughing			30 to 46	2 to 5 Elas
Rubber	30 to 50	J to K	30 to 50	K to M
Sad irons, finishing			80 to 120	O to R
Sad irons, roughing			20 to 30	Q to S
Saws, gunning, sharpening	36 to 50	M to N		
Saws, cold cutting-off	60	O to Q		
Shovels, edging	24	Q to R		
Spiral springs, ends of	16 to 20	Q to R		
Steel (soft), cylindrical grinding	24 comb.	L to P		
Steel (soft), surface grinding	30 to 60	L to O		
Steel (hardened), cylindrical grinding	16 to 36	H to K		
Steel (hardened), surface grinding	16 to 46	J to L		
Steel, large castings	10 to 30	Q to W		
Steel, small castings	20 to 30	P to R		
Steel (manganese), safe work	16 to 46	L to P		
Steel (manganese), frogs and switches	14 to 16	Q to T		
Structural steel	16 to 24	P to R		
Stove castings	20 to 36	P to Q	20 to 36	Q to R
Twist drills, hand grinding	46 to 60	K to M		
Twist drills, special machines	36 to 60	K to M		
Wagon springs, ends of	20 to 30	P to R		
Wire, ends of steel	36 to 50	Q to R		
Wrought iron	12 to 30	P to U		
Woodworking tools	46 to 60	K to M		

watery vapor of volcanic fumaroles in the province of Tuscany, Italy. Following the obtaining of boron products from evaporation of waters a more plentiful supply was obtained from the bottoms of dry lakes or marshes. Deposits of this kind on the Nevada-California border yielded the entire output of borax from that region for many years. The final stage in the development was the discovery of colemanite, a borate of lime containing in the pure state 50 per cent of boron trioxide, in Death Valley, Inyo County, California. The present production of borax and boracic acid is derived wholly from this substance. The colemanite occurs in a form which up to recently was described as a bedded deposit, but of late years geologists have leaned to the view that the deposits are true veins and are a phase of vulcanism. The borax deposits of California are largely under the control of the Pacific Coast Borax Company, which is to-day a subsidiary of Borax Consolidated of London.

In the refining of borax the colemanite rock is first treated at the mine to remove impurity, and roasted to drive off the water of crystallization. It is then shipped East to the refinery at Bayonne, N. J. On reaching the works the ore is again crushed and put through grinding mills. Colemanite is readily decomposed by carbonate of soda, forming borax, or by dilute acids which, on concentration of liquors, yield boracic acid. The crystallizing vats at Bayonne are rectangular in shape, and surface for crystallization is obtained by suspending wires in them. The borax and boracic acid which crystallize on the sides of the vats are imperfect and have to be recrystallized. Following the crystallization the boron products are screened into a large number of sizes. The imperfect crystals forming the undersize of the finest screen are ground in revolving crushers, the impalpable sizes resulting from this operation and from settlement in dust chambers being much used by manufacturers of foot powders. Finely powdered boracic acid is much used by manufacturers of talcum powders. The coarsest crystalline size is used in the enameling trades, this being about pea size; then successively come domestic and pharmaceutical sizes. As is well known, borax makes a clear-colored glass with metallic oxides and reduces the temperature of melting other compounds mixed with the oxides and borax in making enamels.

Canning

Peas are the only canned product which is graded. But some historical matter which will apply to all may be of interest. The first invention relating to canning is that of M. Appert, who secured the prize of 12,000 francs offered by the French government for a method of preserving food for the use of the navy. The complete methods as disclosed by him in a work published in 1819 form the basis for modern canning processes. In brief, Appert's discovery was to heat the material to the temperature necessary to kill all organisms present, and make possible preservation for an indefinite period by hermetically sealing the package. Appert chose glass to hold the food. In 1810 an Englishman took out a patent covering vessels made of metal. The introduction of the tin-coated can, with its cheapness and strength, is what has made possible the enormous size of the canning industry to-day. Among the first to use the method in the United States was Thomas Kensett who, in connection with Ezra Daggert, engaged in the canning business in 1819. The real rise of the American canning industry dates from 1850, from which date the volume of the business began to swell very rapidly. During the eighties of the last century the business fell into disrepute with the public owing to the flooding of the market with inferior products. Practically every canner is to-day a member of a national

association which maintains a laboratory where individual failures are analyzed and the proper temperature, etc., for canning individual products are thoroughly studied, and the results distributed freely to the members of the association. Corn, which offers much difficulty in preserving, was first successfully put out by Isaac Winslow in 1842.

Tomatoes were first packed for commercial purposes about 1847, not because they offered any particular difficulty prior to that time, but because the value of the tomato as a food product was not appreciated earlier.

A description of the canning of peas will serve to illustrate the general steps employed for canning all articles. In the beginning of the pea-canning industry the peas were picked and shelled by hand. This was followed by the invention of the pea huller, a machine which was capable of hulling 1000 bushels of peas in ten hours. This machine was superseded by a form of pea thresher, which shells the whole vines. At present the peas are moved and carried to the factory, where they are fed into the pea thresher or viner. Following the shelling operation the peas pass through the separator, the operation of which is the same as in grain separating. The first separation takes out leaves, sticks, etc. The final separation removes the adhering sand and dirt. These machines will not, of course, separate any impurity in pieces within the range of the size of peas. Following the separator the peas pass through revolving screens, which will be in number to suit the fancy of the individual packer. The size aperture will also depend to some extent on the district, variety grown and the season. Some seasons are favorable to the rapid growth of the size of the pea in the pod, yielding a large quantity of large peas. The packers incline rather to a medium-sized pod rather than a well-distended pod with a large percentage of large peas, for which as good a price cannot be obtained as for a smaller pea. There are usually three sizes made, the little or French pea, the medium-size pea and the large or telephone variety.

Screening for peas differs from ordinary screening in that the smallest pea is removed in the first screen and successively larger sizes on the lower screens. Following the grading operation the peas are hand-picked for removing imperfect and off-color peas, bits of leaf, etc. They are next washed and cooked for a few minutes before putting into the cans. Following the preliminary cooking they are rinsed in cold water and drained, after which they are weighed into the cans. The cans are filled with syrup, the proportion of sugar being varied according to the amount in the pea. Following the canning operation the peas are steamed and then capped. After the capping process the small steam hole is filled with a drop of solder. The cans are then heated to a degree and for a length of time sufficient to destroy all germs in a steam process kettle. The heating of the pea has to be rather carefully regulated, for too high a temperature will break down the structure, make the pea mushy and the syrup cloudy. Too low a temperature will, of course, not give the proper germ-destroying result.

California is to-day the most important canning State, but at the last census Wisconsin led in the canning of peas, the value of the Wisconsin product in 1909 being over \$3,000,000. New York was next at that time, with a valuation of over \$2,000,000. In the matter of rank such statistics are not of much value, as there are very marked changes in this respect from year to year.

Calcium Carbide

This material is sent out in a multitude of grades, from pieces 4 in. in diameter, used for marine gas

buoys, down to 35-mesh. Below this size it is difficult to grade without producing too much powder that would yield too rapid an evolution of gas.

Cement

There is at present no grading problem in this industry. The methods of manufacture are too well known to go into.

Denver, Colo.

The Making of a Big Gun

Faraday Society Meeting

Dr. W. Rosenhain, of the (British) National Physical Laboratory, delivered on April 6 an illustrated lecture under the auspices of the Faraday Society on "The Making of a Big Gun." The lecture was held at the Royal Society of Arts in London.

The lecturer began by contrasting the "big guns" of olden times with the gigantic weapons of to-day. The older guns were made of cast iron, and guns of that material reached their highest development in the American Civil War. The conditions existing in modern guns were illustrated by sectional diagrams relating to guns of fairly recent date, in which pressures of 18 tons per square inch and muzzle velocities of 2500 feet per second occurred. To resist these conditions, the best possible steel was required, and even that only served for a comparatively short time. The work of modern guns was illustrated by some photographs of gigantic projectiles which had been recovered intact after penetrating great thicknesses of modern armour. The effect of use on the inside of a gun was illustrated by photographs showing the "erosion" and the cracking which occur as the result of the high temperature of the explosion gases.

The lecturer then proceeded to describe the modern process of gun-making by the aid of a series of cinematograph pictures of the most interesting and striking stages of the process. These films had been prepared and lent by Messrs. Vickers, Ltd., at whose Sheffield works they had been taken. The series began with the blast-furnaces in which the iron ore is reduced by the aid of coke and limestone; next came the open hearth steel furnace and the processes of filling were shown, and particular attention was drawn to a picture which clearly showed the "boiling" of the molten steel within the furnace. Throughout the various stages of the process, including the refining of the iron to transform it into steel, its various stages of forging, hardening, and tempering, the lecturer gave in popular terms the scientific reason for each step, illustrating his remarks by a series of photomicrographs showing the minute structure of the steel at each stage, and showing how each step served to bring the steel nearer to the ideal condition of perfect homogeneity. The lecturer naturally avoided reference to those confidential matters which relate to the most recent products of the steel-maker's art as directed to the production of guns, but as an indication of the direction in which modern practice tended, he showed the extremely minute micro-structure which can be produced by proper treatment in modern special or "alloy steels." The extreme importance of accurate scientific control, of compositions, temperatures, and rates of cooling, throughout the process, was strongly emphasized and illustrated.

By means of the series of cinematograph films the gun was followed through its various stages, from the freshly cast ingot weighing 80 tons, through the processes of "cropping" and "trepanning," as the first piercing of the ingot to form a rough tube is called, on through the forging press until it attains its requisite

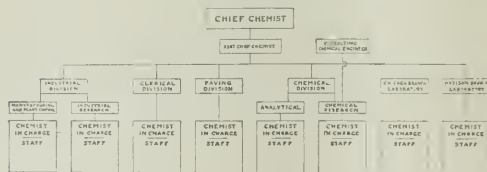
length—in some cases over 70 feet. Then follow the machining operations, and then what is, perhaps, the most delicate part of the process—hardening and tempering, in which the roughly machined tube is heated to a uniform and carefully regulated temperature in a tall chimney-like vertical furnace, from which it is lifted at the proper moment to be plunged into an oil-bath contained in a deep cylindrical well. The process of rifling and the finishing of the outside, after the application of the wire-winding, were also shown. Finally, as a relief to the more severely technical portions of the lecture, some films were shown illustrating the testing and firing of big guns.

The President of the Faraday Society, Sir Robert Hadfield, in proposing a vote of thanks to the lecturer, supplemented what he said by some further interesting information with regard to the achievements of modern artillery. He spoke, for example, of 16-in. American guns firing a shell of 2400 lb. weight a distance of 21 miles, and of 12-in. armour plate fired at from a distance of 1½ miles being cracked but not perforated. The wire-wound gun described by the lecturer was found to be the finest in the world, and it had the advantage of being cheaper than enemy patterns. It was not usually realized that the life of a large gun, based on the time of actual fire, was not more than three seconds.

A curious fact was that the soft-nosed cap used on modern shell expanded so rapidly on striking an object as to allow the complete shell to pass through it. In referring to the great importance of metallurgy in gun-making engineering, Sir Robert Hadfield told of a 15-in. shell which can pass through 15-in. armour plate in no more than 1/1000 of a second, and of a 6-in. shell fitted with a modern cap which he had seen fired three times before the shell was broken.

Laboratory Organization of an Asphalt Company

Below is a chart showing the organization of the laboratory forces of The Barber Asphalt Paving Company, the work of which was described in METALLURGICAL & CHEMICAL ENGINEERING of May 1, under the title of "A Company that Makes the Most of Its Chemists."



The special duties of each division of the laboratory were described in the article just referred to.

The first annual convention of the American Association of Engineers was held in Chicago, May 9 and 10. Two afternoon informal sessions were held in the rooms of the Western Society of Engineers, 1733 Monadnock Block. The annual dinner was held at the City Club. No long papers were permitted at the informal sessions, but discussions of several vital subjects were made by prominent engineers.

Testing Volumetric Apparatus.—A bulletin has been issued by the Bureau of Standards (Circular No. 9) entitled "The Testing of Glass Volumetric Apparatus," containing specifications and tolerances for such apparatus and also a short description of methods of test.

The Chemical Analysis of Rubber Goods

BY ANDREW H. KING

Under this head comes some of the most difficult work the analytical chemist has to perform. Most of the difficulties are due to the colloidal nature of rubber, and to the fact that there is no simple, easy and direct method for the determination of the rubber content. Obviously one very important question in regard to any sample is: "How much rubber is present?" To answer this we must use various indirect methods, and their accuracy is sometimes in doubt.

In the early days of the rubber industry it was customary to determine the rubber content by difference. This was done by adding the mineral matter (determined by ashing) and the total sulphur, and subtracting the sum from 100. It is hardly necessary to state that this method was quite crude and inaccurate. For example, many substances such as substitute, oils, ground leather, etc., could be used to replace considerable percentages of rubber without detection. To remedy this condition recourse was had to various extractions, with such solvents as acetone, chloroform, alcoholic potash, and water. By a proper interpretation of these results, correction can be made for adulterants, and a reasonably correct figure for the rubber content obtained.

It was found, however, that variable extracts could be secured from the same sample by the use of different forms of extractors, and by varying the conditions of extraction. For example, a sample of fire hose may show an acetone extract of 2 per cent in a Soxhlett, but when extracted in the Underwriters' form, at the boiling point of the solvent as much as 2.5 per cent may be secured. This variation seems to be due to the colloidal nature of the rubber hydrocarbon, owing to the difference in adsorption under various conditions.

Because of the variations in the several extracts, attempts have been made to standardize the practice. Perhaps the best of these standard methods of rubber analysis are those of the Bureau of Standards, the Joint Rubber Insulation Committee, and the Underwriters' Laboratories of Chicago. These methods have been evolved for specification work, and the rubber chemist usually modifies them according to his own needs.

In this article I will endeavor to set forth a satisfactory procedure for general work. The methods given are, in my opinion, the most satisfactory of those published, and no claim for originality is made. It is my aim to place in the hands of the chemist not connected with the rubber industry, a tool which will enable him to satisfactorily differentiate between a good and a poor article. Proper inspection of a shipment of rubber goods demands both physical and chemical testing. The former shows the present state of the material, and by the latter we can predict as to its condition in the future.

Preparation of Sample

It should be the aim of the chemist to see that the sample he analyzes is not contaminated by any foreign material. In other words, that it is a true sample. For example, an analysis of a fire hose tube should be made on the tube alone; that is, with the backing buffed off. The clean sample must then be finely divided. This is best performed by passing it through the rolls of a small mixing mill. The Underwriters' Laboratory uses a motor-driven mill, having rolls 6 in. x 12 in., the front roll smooth and the drive roll corrugated. In the absence of a mill, a food chopper can be used to advantage. In the case of hard rubber, the sample is prepared by rasping with a file.

Reagents

Acetone should be freshly distilled over anhydrous potassium carbonate, using the fraction 56 to 57 deg. C. Technical acetone may be purchased and purified as above. The residue on evaporation must be negligible.

Chloroform should be the purest obtainable, the grade used for anesthesia is satisfactory.

Ether specifications are the same as for chloroform.

Alcoholic potash should be of normal strength, and may be prepared by adding just enough water to the required weight of potassium hydroxide (C.P. by alcohol) to dissolve it. This solution is added to the desired quantity of alcohol, which has been previously boiled for two days under a reflux condenser with sodium hydroxide, and later distilled. When completed, the resulting solution should contain approximately 95 per cent alcohol by volume.

Water used is best double distilled, neutral to litmus paper, and should show no weighable residue on evaporation of 500 c.c.

All other reagents should be C.P.

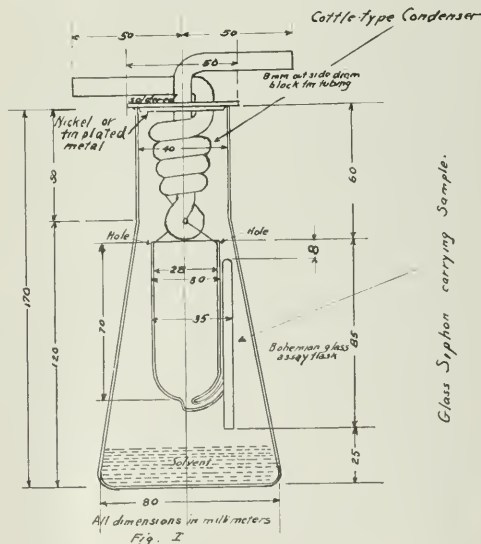
Determinations

The determinations made in a complete analysis are as follows:

1. Acetone extract. (a) Free sulphur. (b) Waxes.
2. Chloroform extract.
3. Alcoholic potash extract.
4. Water extract.
5. Total sulphur.
6. Ash and mineral analysis.
7. Total fillers and rubber.
8. Specific gravity.

It is not always necessary to make every determination. The chemist must use his own judgment as to the demands of the particular case he has in hand.

Acetone Extract.—A 2-gram sample is wrapped in cloth, which has been previously treated with acetone to remove vegetable waxes, and the whole extracted over night with 50 to 60 c.c. of acetone in a weighed flask. This applies only to soft rubbers. Hard rubber samples must be extracted for three successive days. The acetone is



Joint Insulation Committee Standard Extraction Apparatus.

then distilled off, and the flask dried to constant weight in an oven, at 95 to 100 deg. C. Cool in a desiccator, and weigh. When the extract is to be examined for waxes, etc., it is best to use that from the 2-gram sample for the determination of the free sulphur, and to separately extract a 5-gram sample. When the bulk of the 5-gram sample is such that the extractor will not hold it, it may be divided into two portions, and run over two nights. The apparatus used, Fig. 1, is that recommended by the Joint Rubber Insulation Committee.

The extract so secured contains the natural rubber resins, the free sulphur, and any added resins, oils, or waxes. It also contains a portion of any tar or asphaltic material, such as mineral rubber, when present. Most organic vulcanization accelerators are soluble in acetone, and are to be found in this extract.

The acetone extract is one of the most important determinations made. Properly interpreted, it aids greatly in showing just what has been added to the compound in the course of manufacture. The color of the extract is a good indication. From high-grade compounds the extract should never be darker than a light straw color, and the net extract, that is, after subtracting the free sulphur, should not exceed 5 per cent. Mineral oil, tar, or asphaltic material causes a fluorescent extract. When present in quantity they darken the color to a brownish black. Even a small percentage serves to give fluorescence. This is an additional indication of the presence of shoddy, which very frequently contains mineral oil in the form of vaseline, which is added to make the material more plastic and workable.

When a determination of the wax is desired, the extract from the 5-gram sample is used. This is accomplished by the method of Weber. The dried extract is warmed with about fifty times its weight of glacial acetic acid. On cooling, paraffine wax separates almost quantitatively, and can be filtered off and weighed. A partial separation of the various constituents of the acetone extract may be accomplished by the use of absolute alcohol according to the following scheme. Allen, *Commercial Organic Analysis*, Vol. IV, page 124.

SEPARATION OF THE ACETONE EXTRACT BY MEANS OF ALCOHOL

Soluble	Insoluble
Free fatty acids	Fatty and mineral oils (except
Resins (colophony)	castor and blown oils)
Waxes (beeswax, carnauba)	Tar oils, solid hydrocarbons
Castor and blown oils	

The extract is warmed with absolute alcohol, filtered from insoluble matter; on cooling below 0 deg. C. the soluble waxes are precipitated. Considerable work is yet to be done at this point, for there is no entirely satisfactory method for the separation and quantitative estimation of the different constituents of the acetone extract.

Frequently considerable stress is laid upon the determination of the saponifiable matter. That is accomplished in the same general manner subsequently described under the alcoholic potash extract, except that the soap solution is not acidified. The dried acetone extract is covered with about 30 c.c. alcoholic potash and boiled for five hours, using the Cottle condenser. The solution is filtered, and any residue washed with alcohol and hot water. The filtrate is evaporated to small bulk, diluted with cold water, and shaken with ether in a separatory funnel. The ether extract is washed once with water, and the ether evaporated from a weighed flask. On drying and weighing, a measure of the unsaponifiable matter is obtained. In a high-grade article, where no organic fillers have been added to the mixing, this figure is indicative of the kind of rubber used. It serves also to indicate the amount of

fatty oils present. The Joint Rubber Insulation Committee allows 1.35 per cent saponifiable acetone extract on 30 per cent rubber insulation.

Free Sulphur.—The term "free sulphur" is really empirical. On the surface it would seem to mean uncombined sulphur, as opposed to the combined, that is sulphur of vulcanization. When vulcanization was first investigated from a scientific standpoint, the samples were extracted with acetone, and the sulphur determined in the extract. This figure they called free sulphur. Soluble, or extractable sulphur, would have been more appropriate. The extractor first used was the Soxhlett. As the reader will recollect, in this form the solvent is contained in a flask which rests on a water bath. On boiling, the vapors pass up through a side tube to the extractor, and from there to the condenser, where they are condensed. The liquid falls upon the sample, which is contained in a paper thimble in the extractor. When the level of solvent reaches a certain height, the siphon tube is filled, and the solvent flows back into the original flask. It is obvious that the solvent in the extractor is comparatively cold. On reference to Fig. 1 it will be seen that the solvent which comes in contact with the sample in the Insulation Committee form is at a much higher temperature. In fact, the liquid in the siphon cup is nearly always boiling. So in speaking of this form, extraction is said to be made at the boiling point of the solvent. Practically all commercial acetone extracts are now made in this manner. As a matter of scientific interest, the work of Skellon (*Proceedings International Rubber Congress, 1914, London*) should be mentioned. By extracting under pressure, he was able to obtain a higher temperature of solvent, and thus remove still more sulphur from a sample previously extracted as above described. Evidently the end is not yet, and much work must still be done before we can determine for a surety the true percentage of free sulphur, and as a corollary, the amount of combined sulphur.

The extract from the 2-gram sample, which has been previously dried and weighed, is treated with 10 c.c. fuming nitric acid. Warm on the water bath. When solution is complete, add 1 gram of powdered anhydrous potassium chlorate, and run nearly to dryness. Add 5 c.c. concentrated HCl, and run to dryness; repeat to expel any remaining nitric acid. Take up with hot water, acidify slightly if necessary with HCl. If the solution is cloudy, filter. Heat to boiling, and add a boiling solution containing 10 c.c. of 10 per cent barium chloride solution diluted somewhat with water. Let stand over night, filter, ignite, and weigh.

In many kinds of mechanical goods the free sulphur is not overly important. In high-grade articles it should be less than 1 per cent in order to age properly. In making a non-blooming gray inner tube, the aim is to keep the free sulphur below one-half of 1 per cent. By blooming is meant the formation of a surface scum of finely divided colloidal sulphur. When the free sulphur is high, the colloidal particles coalesce into well-defined sulphur crystals. Articles that are to be subjected to relatively high temperatures must have a low free sulphur (less than $\frac{1}{2}$ per cent), so that they will not become brittle. For example, the cover of a belt conveyor, designed to carry hot clinker, must be so compounded that the free sulphur will be very low, otherwise the rubber will be vulcanized beyond the point of its greatest elasticity, thus causing surface hardening and ultimate failure.

Chloroform Extract.—The same apparatus as previously described under extraction with acetone is used for chloroform. It is not necessary to dry the acetone extracted sample, but only to squeeze out the excess.

The sample is extracted for four hours with 50 c.c. of chloroform. If after this time the solvent in the extractor siphon is still colored, the extraction is continued until clear, and one hour thereafter. The chloroform is distilled off, and the flask dried to constant weight in an oven at 98 to 100 deg. C.

High-grade material will give an almost colorless chloroform extract, and not over 1½ per cent on a 45 per cent rubber compound. Less valuable articles will give a higher extract, having a yellow color. A brown to dark brown extract is indicative of mineral rubber, tar, or other asphaltic material. The behavior of mineral rubber is worthy of mention. Ordinarily it is partially soluble in acetone, and entirely so in chloroform. But upon mixing with sulphur and the other ingredients of a rubber compound and vulcanizing, a portion of the mineral rubber becomes insoluble in both acetone and chloroform. As yet we have no accurate method of determining the percentage of this substance after vulcanization.

Alcoholic Potash Extract.—The sample, following the chloroform extraction, is removed from its cloth sack and dried for one-half hour in an oven at 50 to 60 deg. C., or allowed to stand over night at room temperature, to free it from chloroform. It is then placed in an extraction flask with 50 c.c. normal alcoholic potash solution. The Cottle condenser is put in place and boiling is continued for four hours. At the end of this time the flask is emptied upon a filter, washed with at least 50 c.c. of hot absolute alcohol, and following with hot water. The filtrate and washings are evaporated on the water bath until the volume is reduced to about 20 c.c. Distilled water is added to bring up the volume, and the whole poured into a separatory funnel, where it is just made acid with dilute HCl and 3 c.c. excess. This solution is shaken out with ether, using 20 c.c. portions until the ether layer is clear, then three times thereafter with 10 c.c. portions of the solvent. The ether extracts are combined, washed once with water, and placed in a weighed flask. The ether is distilled off, the flask dried at 98 to 100 deg. C. to constant weight. On good material (50 per cent rubber) the alcoholic potash extract should not exceed 1½ per cent. A high extract indicates the presence of rubber substitute. Its use is permissible only in low-grade articles. The extract contains the fatty acids of the oils in preparing the substitute. These may be taken as representing approximately 80 per cent of the total percentage of substitute present.

Water Extract.—Sometimes such substances as starch and dextrine are added as a filler. When such are thought to be present, a 1-gram sample is placed in a cloth sack and boiled with distilled water for four hours. The sack is removed and any absorbed liquid squeezed out. The solution is evaporated to dryness, and weighed. The determination of water extract is now almost unnecessary, since water soluble fillers are avoided as much as possible in compounding.

Total Sulphur.—There are many methods proposed for the estimation of total sulphur, but the Bureau of Standards' modification of Henriques method seems to give more uniformly accurate results.

A ½-gram sample is placed in a porcelain crucible of about 100 c.c. capacity. A nitric acid bromine mixture is prepared by saturating concentrated nitric acid with bromine and allowing it to stand some hours before using; 20 c.c. of this mixture are added gradually to the contents of the crucible. Let stand for one hour, then place on the water bath and heat for another hour, rinse off the cover, and evaporate to dryness. Add 5 grams of fusion mixture, which is prepared by mixing equal parts sodium carbonate and potassium nitrate,

and 3 to 4 c.c. of water. Digest for a few minutes, and spread the mixture half way up the sides of the crucible to facilitate drying. Run to dryness on the water bath. Fuse, using a sulphur free flame, and continue heating until all organic matter has been destroyed and the melt is plastic. Allow to cool, place the crucible in a 600 c.c. beaker, cover with distilled water. Digest on the water bath until solution is complete. Filter into an 800 c.c. beaker, washing thoroughly with hot water. The total volume should be around 500 c.c. Acidify with concentrated hydrochloric acid and boil. Add 10 c.c. 10 per cent barium chloride solution as under the determination of free sulphur. Let stand over night, filter, ignite, and weigh.

The total sulphur reported by this method includes the sulphur added to the compound in mixing, and also that of any sulphur-bearing fillers, such as barytes, lithophone, gypsum, etc. Therefore proper correction must be made before the added sulphur can be estimated. This is best done by taking the separated total fillers secured by the method later to be described, and treating this sample, with a few cubic centimeters of the nitric acid bromine mixture. Run to dryness, and fuse with 5 grams of the standard fusion mixture, according to the method given above. It is, to my mind, a waste of time to determine the percentage of sulphur present in the ash, since more or less of the sulphur present, even the combined sulphur, is taken up by any litharge present, forming lead sulphate. Zinc oxide is partially converted to zinc sulphate.

Ash and Mineral Analysis.—This determination was formerly given considerable weight. While it is important, and will at times give valuable information, there are certain factors which must not be lost sight of.

The method is as follows:

A 1-gram sample is wrapped in a piece of 589 filter paper, and extracted over night with acetone in the regular manner, thus removing the free sulphur. The sample is then dried and ignited in a weighed porcelain crucible. The ignition is best performed in an electrically heated muffle. When such is not available, an Argand burner may be used. The temperature should be so regulated that there are no visible fumes, and the heat gradually increased until all the carbon is burned off. The time of ashing should not be unduly long; six hours seems to me about the maximum. Longer ashing will lead to the formation of considerable lead sulphate, so that the figure for ash will be much too high. The temperature of the crucible should always be as low as possible, so that no carbonates will be decomposed. When vermilion, antimony golden sulphide, or carbon are present, the ash determination is no longer a measure of the fillers, since these substances are wholly or partially volatilized. A sample of rubber which is to be analyzed for antimony or mercury is best dissolved by the following method:

A ½-gram sample is oxidized with 10 grams ammonium persulphate and 10 c.c. fuming nitric acid in a 100 c.c. flask. After the principal reaction, which takes place in the cold, has ceased, the flask is carefully heated. If after fifteen minutes' digestion red particles of mineral or organic matter are still visible, 3 grams more of ammonium persulphate are added. Too strong heating must be guarded against, as this tends to produce insoluble combinations. After heating, the flask is allowed to stand until crystals begin to form, when 10 c.c. concentrated hydrochloric acid are added. After solution takes place, it is diluted with hot water, and the insoluble matter filtered off. Proceed from this point according to the customary analytical methods.

When an analysis of the ash is desired, it is made

according to the usual practice of quantitative analysis. The following list includes most of the fillers ordinarily added to a rubber compound:

Silica.

Iron and aluminium oxides and silicates.

Barytes.

Lead in the form of litharge, basic or sublimed white lead.

Zinc in the form of oxide or sulphide in lithophone.

Lime and whiting.

Magnesia and magnesium carbonate.

Antimony in the form of golden sulphide.

In cases where pigments have been used, only the dry colors and lakes need be looked for. For example, a green color will usually be due to chrome green, a blue to ultramarine. Red is secured by vermilion, iron oxide, or antimony sulphide. Copper and manganese should never be present.

The advantage of the ash determination is that the rubber content may be arrived at quickly by adding the ash and the net total sulphur (total sulphur minus inorganic sulphur), and subtracting the sum from 100. By making proper corrections, according to the amounts of the various extracts, a more nearly correct figure may be reached.

Total Fillers.—When a more nearly accurate figure for rubber is desired, or in the presence of vermilion, lamp black, etc., recourse must be had to other methods. There are several direct methods proposed for the determination of rubber, but they are rather complicated and require so many corrections that none can be called entirely satisfactory. Another way of approach is to dissolve out the rubber by means of a suitable solvent, and filter off the total fillers. In this manner such fillers as ground leather, cotton waste, etc., are not lost as they would be in ashing.

A satisfactory method for this determination follows:

A 1-gram sample is placed in a 400 c.c. flat-bottomed flask and covered with 50 c.c. purified nitrobenzole. This is connected to an air-cooled reflux condenser. If ground glass joints are not available, cork, covered with tinfoil, may be used. Begin digesting very slowly on the water bath to avoid carbonization. Finally heat to the boiling point of the solvent. Continue the operation until the sample is decomposed. Cool, fill the flask with acetone, and allow to settle. Filter through a weighed filter paper, washing with acetone. Dry, and weigh.

When lamp black or other organic matter is to be determined, treat the filter paper carrying the residue with hydrochloric acid to decompose any carbonates. Filter, using a weighed paper. Dry, and weigh. Calculate the loss due to carbon dioxide, and ignite in a porcelain crucible, as under ashing. The loss will be organic matter.

By this method the percentage of total fillers is secured. Oils, dopes, etc., must be estimated from the extracts. In filtering the rubber solution there are difficulties, since the rubber colloid exerts a protective action, thus preventing a rapid settling of the mineral fillers.

By dividing the percentage of net acetone extract, that is, minus the free sulphur, by the percentage of rubber, a figure is secured which when multiplied by 100 is called the resin on rubber. When no organic fillers have been added to the compound, this figure aids in saying what kind of rubber has been used. For example, the resin on rubber of Plantation Smoked Sheets varies from 2½ to 4½ per cent, while that of Coarse Para varies from 1 to 2½ per cent. A high resin on rubber indicates added resins, oils, or waxes, low-grade rubber, or shoddy.

The coefficient of vulcanization is obtained by subtracting the free sulphur from the added sulphur, and dividing this figure by the percentage of rubber and multiplying by 100. It shows the ratio of combined sulphur to rubber substance. This ratio varies, depending upon the kind of material being prepared. Thus, for inner tubes, it is usually around 2.5. For fire-hose tubing it is around 4.0, hard gaskets and valves 10 to 20, and for the highest possible vulcanized condition it is 32. The presence of shoddy increases this ratio, thus a shoddy hose may have a coefficient of vulcanization of 10 or 12, and still remain elastic. In general, shoddy is indicated by high coefficient of vulcanization, a high resin on rubber, and a fluorescent acetone extract.

Let me repeat what I said in a previous article—the presence of shoddy is not necessarily a basis for condemnation. Fit the material to the purpose, for high duty use high-grade rubber, for easier conditions use the poorer variety.

Specific Gravity.—The specific gravity of a sample was at one time given considerable weight, due to the idea that of two samples the one having the lower gravity contained the most rubber. The inaccuracy of this does not require demonstration.

The determination is made according to Archimedes' principle, weighing first in air and then in water. Divide the weight in air by the loss of weight in water for the gravity. Use a sample of 3 to 5 grams, and take care that all air bubbles are removed before weighing in water. Perhaps the best compounds have a gravity of 1.50 to 2.00. Inner tubes usually have a gravity of less than 1.00.

Summer Session in Scientific Management

The Pennsylvania State College Bulletin for June, 1916, contains an announcement of the second summer session in factory organization, cost-accounting and scientific management conducted last year by Professor Hugo Diemer. The session will be held August 7 to 19. Professor Diemer is assisted by Mr. W. H. Tabor, who has had considerable experience in scientific management along the lines followed by the late Frederick W. Taylor.

The 1915 session resulted in the establishment of interesting acquaintanceships and the interchange of much valuable information. The age of those attending ranged from twenty-five to over sixty years, and while there were only eleven men who attended the session the interest shown makes it probable that this year the limited number of thirty will take the course.

The list of subjects includes a very wide variety under two main headings, viz.: "industrial organization" and "scientific management." Shop work in a variety of subjects relating to the work, is included in the two weeks' curriculum.

The Chamber of Mines and Oil of Los Angeles, Cal., held its annual meeting and dinner at the Jonathan Club on Tuesday, May 2. Addresses were made by Seeley W. Mudd, Warren C. Kennedy and Theodore Martin, and motion pictures were shown of Cerro Azul, No. 4, said to be the world's greatest oil well. The pictures were exhibited and explained by Mr. Edward L. Doheny.

Preparation of Pure Iron and Iron-Carbon Alloys.—The Bureau of Standards has recently issued a bulletin (Scientific Paper 266) describing the preparation of iron and a series of iron-carbon alloys of a high degree of purity to be used in the study of the iron-carbon equilibrium diagram.

The Effect of Vacuum Fusion Upon the Magnetic Properties of Pure Open Hearth Iron

BY TRYGVE D. YENSEN

Research Assistant Professor, University of Illinois.

In a number of articles¹ during the last two years the writer has described the remarkable magnetic properties obtained by melting electrolytically refined iron *in vacuo*. It has been shown that it is possible by this process to obtain magnetic permeabilities ($\mu = B/H$) as high as 50,000, accompanied by hysteresis losses of 1/5 to 1/8 that of the best commercial transformer steels in use at the present time. The question has naturally arisen: What effect will the vacuum treatment have upon commercial grades of iron? In order to answer this question one of the purest grades of commercial iron obtainable was selected for an investigation. The composition of this iron which was made by the open hearth process according to the most approved method is as follows²:

S.....	0.025 per cent
P.....	0.005 per cent
C.....	0.010 per cent
Mn.....	0.025 per cent
Si.....	0.005 per cent
Cu.....	0.050 per cent
O.....	0.035 per cent
N.....	0.004 per cent
H.....	0.001 per cent
Fe (by diff.).....	99.84 per cent
	100.00 per cent

Test pieces were prepared from this iron as it was received from the manufacturer, and others were prepared from the iron after being remelted in *vacuo*. The test pieces consist of rods, 1 cm. x 36 cm., used in connection with Burrows' compensated double bar and yoke method, and of rings, 4.2 cm. outside diameter x 3.8 cm. inside diameter, tested by the ordinary ballistic method. These test pieces before the final testing were annealed at 1100 deg. C. in *vacuo* and cooled at the rate of 30 deg. C. per hour to room temperature.

The results obtained are given in the accompanying

¹ Bulletins No's 72, 77 and 83, Eng. Exp. Sta., Univ. of Ill. Transact. A. I. E. E., 1914, Vol. 33, part 1, p. 451. Proc. A. I. E. E., Oct., 1915, p. 2455. Proc. A. I. M. E., Feb., 1916, p. 483.

² These figures have been supplied by the manufacturer and are said to be representative of the iron. Analyses made by the Chemistry Department of the University of Illinois check these figures satisfactorily.

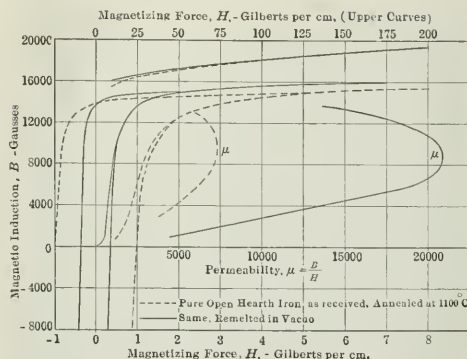


FIG. 1.—MAGNETIC TEST CURVES OF PURE OPEN-HEARTH IRON AS RECEIVED AND REMELTED IN VACUO

table and in Fig. 1. It is seen that the vacuum treatment has increased the maximum permeability from two to three times and decreased the hysteresis loss by a corresponding amount.³ For the sake of comparison there have been included in the table the results previously obtained with electrolytic iron—with and without additions of silicon—melted in *vacuo*. This comparison shows plainly that *nearly* as good results are obtainable using pure open-hearth iron as a base as with the pure electrolytic iron.

As far as the chemical analysis is concerned it is difficult to point out any material difference between the open-hearth iron before and after the vacuum treatment. Only as far as the CO and CO₂ gases are concerned it may be stated that there has been a material reduction by the vacuum treatment. In order to obtain further information regarding possible differences, samples were examined for density and under the microscope. The density tests showed very slight differences between the treated and untreated iron, but out of a number of tests under different conditions and by dif-

³ A similar improvement has been obtained with Swedish charcoal iron. See Bull. No. 72, Eng. Exp. Sta., Univ. of Ill., pp. 25 and 33.

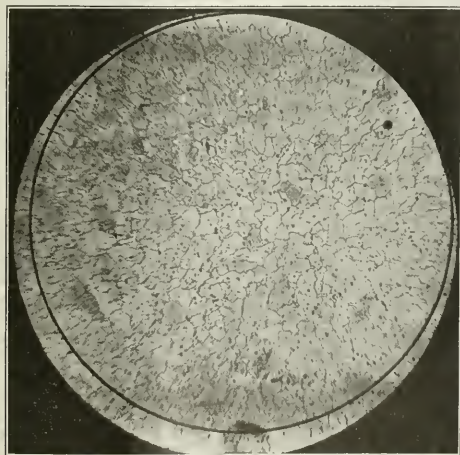


FIG. 2a—60 DIAM.—PURE IRON MADE IN OPEN-HEARTH FURNACE



FIG. 2b—360 DIAM.—PURE IRON MADE IN OPEN-HEARTH FURNACE

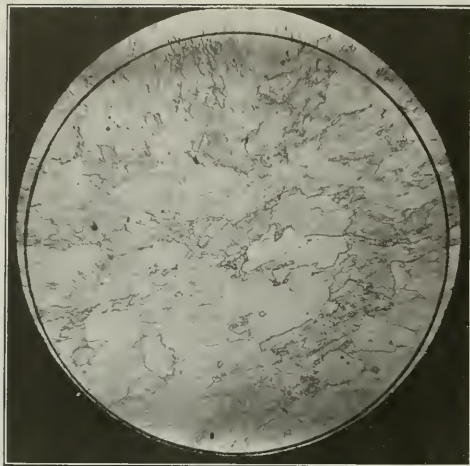


FIG. 3a—60 DIAM.—OPEN-HEARTH IRON REMELTED IN VACUO

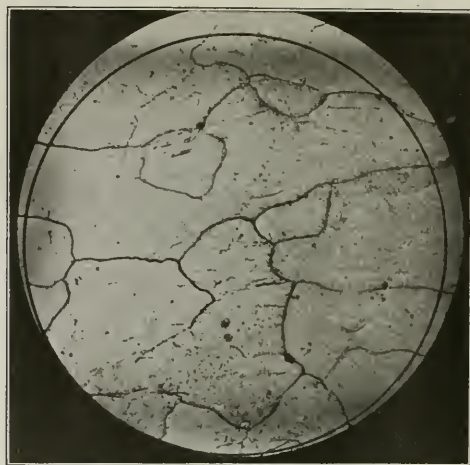


FIG. 3b—360 DIAM.—OPEN-HEARTH IRON REMELTED IN VACUO

ferent persons the density of the vacuum-treated iron was in every case found to be higher, the average difference being about 0.1 per cent.

Figs. 2 and 3 show the photomicrographs obtained for the two samples examined. In Figs. 2a and 2b it is seen that in the untreated iron, while it is remarkably free from slag or other impurities such as are generally met with in commercial iron, there appear a large number of minute spots, evidently cavities caused by dispelled gases. The vacuum-treated iron is practically free from such cavities as seen by Figs. 3a and 3b. Furthermore, the crystals of the treated iron are much larger than those of the untreated iron.

The results thus far obtained seem to indicate that the purer the iron the larger are the crystals. Previous results also point towards a possible connection between high magnetic permeability and large crystals when comparing irons of the same general composition having received the same mechanical and heat treatment. It may be a question, however, whether magnetic permeability has anything to do with the crystal size, as it may depend solely upon the purity of the iron. In favor of this contention may be cited the fact that when pure iron has been annealed at temperatures above 900 deg. C., followed by slow cooling, the resulting crystals are much smaller than after annealing at or below 900 deg., and yet the magnetic permeability is generally increased by annealing at the higher temperatures.

From these facts and indications the only safe conclusion that may be drawn is that the open-hearth iron has been purified by the vacuum treatment to a degree not obtainable by any ordinary process of manufacture, and, furthermore, that this purification has resulted in marked improvements in the magnetic properties. Together with the results previously obtained with Swedish charcoal irons (compare footnote 3), these results show definitely that it is possible to obtain magnetic properties with commercial grades of iron by vacuum fusion that are comparable with those obtainable with electrolytic iron.

Industrial Index.—A cumulative index of the industrial arts, made from about 80 trade and engineering journals is issued in April, June, October and December by the H. W. Wilson Co., White Plains, N. Y. The December number contains the annual cumulation.

TABLE I.—A COMPARISON BETWEEN THE MAGNETIC PROPERTIES OF OPEN HEARTH IRON BEFORE AND AFTER BEING REMELTED IN VACUO. ALSO COMPARED WITH ELECTROLYTIC IRON

Specimen No.	Kind of Specimen	Max. Perm.	Density for Maximum Permeability		Permeability		Hysteresis Loss, Ergs per Cub. Cm. per Cycle		Retentivity in Gauss		Coercive Force in Gilberts per Cm.		Spec. Elec. Resist., Microhm
			B=10,000	B=15,000	B=10,000	B=15,000	B=10,000	B=15,000	B=10,000	B=15,000			
OPEN HEARTH IRON, AS PURCHASED Machined From 1/2-Inch Rod. Annealed at 1100 Deg. C.													
1.A.R.	Rod	7,250	10,000	7,250	2710		5550	9000	13,000	.85	1.0	10.15	
OPEN HEARTH IRON REMELTED IN VACUO, ANNEALED AT 1100 DEG. C.													
2.4-01	Ring	14,300	8,500	13,700	5700	986	2063	8400	12,300	33	.39		
4-01	Rod	14,180	8,500	13,200	5350	1080	2190	8700	12,300	37	.40	10.05	
4-02	Ring	16,500	9,500	16,450	6400	935	2010	8700	13,900	30	.35		
4-03	Ring	17,000	9,000	16,700	8250	852	1755	8400	12,600	28	.33		
4-03	Rod	20,900	9,000	20,200	7500	865	1760	9300	13,600	30	.34	10.20	
4-04	Ring	16,300	10,000	16,300	6000	870	1880	8400	13,300	30	.35		
ELECTROLYTIC IRON MELTED IN VACUO, ANNEALED AT 1100 DEG. C.													
3.3-54	Rod	22,800	8,000	21,300	1365	665	1860	9300	13,300	20	.24	9.84	
3-55	Rod	25,800	9,000	25,600	1365	707	1451	9300	12,700	.23	.28	9.85	
ELECTROLYTIC IRON WITH 0.15 PER CENT Si MELTED IN VACUO, ANNEALED AT 1100 DEG. C.													
4.3S-06	Rod	66,500	6,500	41,700	6000	286	916	9080	12,000	.09	.165	11.50	
ELECTROLYTIC IRON WITH 3.0 PER CENT Si MELTED IN VACUO, ANNEALED AT 1100 DEG. C.													
5.3S-40	Ring	36,200	8,000	31,300	790	337	757	7700	11,000	.09	.10		
3S-40	Rod	72,600	9,000	69,500	2500	254	926	9400	13,700	.09	.16	44.75	

Newark to Hold Industrial Exposition.—In conjunction with the big celebration of its 250th anniversary, which commenced May 1 and will last to Oct. 1, Newark, N. J., will conduct an industrial exposition at the First Regiment Armory in that city May 13 to June 3. Over 133 lines of industry will be represented in about twice that number of exhibits. Newark is the center of large and varied manufacturing industries, and the exposition will be officially opened by Secretary of War Baker on Saturday, May 13.

Electrolysis of Alkaline Solutions of Potassium Sulphocyanate

BY WELTON J. CROOK,* L. E. BOOTH AND ARTHUR THIEL

Sulphocyanates are invariably present in the cyanide solutions resulting from the cyanidation of ores containing sulphides, more particularly ores containing the sulpho-salts of silver, since the dissolution of the silver from such ores involves the breaking up of the sulpho-compound to the extent that silver is dissolved, with the consequent formation of sulphocyanate. The alkaline sulphocyanates are very stable and, in general, are not solvents for the precious metals. Due to their stability, cyanide available for dissolution is not regenerated from them at any stage of the process unless electrolytic precipitation be used.

The first investigation upon the effect of electrolysis upon the alkaline cyanates under plant conditions was done by Clevenger and Hamilton¹ at Minas Prietas, Mexico, in 1907. An account of this work was never published, but it, together with work done later at Virginia City, Nev., by Clevenger, covered practically the same ground as that which has been later recorded by Clennell.

The purpose of the authors in making the investigation, of which this paper gives an account, was to study the reactions taking place during the electrolysis of aqueous solutions of the alkaline sulphocyanates in more detail than had been previously done. In 1911 Clennell² investigated, in a rough way, the effect produced by electrolyzing an aqueous solution of potassium sulphocyanate. He did not record the voltages used in either of his series of electrolyses, but stated that he used in his second series a current density of from 20 to 35 amp. per square foot of anode surface.

The results of Clennell's work are shown in Table I. The solution used in the first series consisted of: water, 60 lb.; commercial potassium sulphocyanate, 3 lb.; lime, 350 grams. This would approximate a 5-per cent solu-

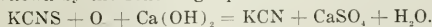
TABLE I.

Time Test	Free KCN, Per Cent	Total KCN, NaOH, Per Cent	Alkali, Per Cent
Before applying current	0.0025		0.210
After electrolyzing 1 hour	0.008	0.0115	0.202
After electrolyzing 24 hours	0.105	0.107	0.173
After electrolyzing 48 hours	0.117	0.118	0.098
After electrolyzing 72 hours	0.132	0.133	0.060

*Fresh lime added—50 grams.

tion. The solution was agitated by paddles and electrolyzed with hard carbon electrodes having an effective area of 1/7 sq. ft.

Clennell states that potassium sulphocyanate is decomposed by electrolysis, in the presence of an alkali, as shown by the following equation:



Investigation of Methods of Analysis

The most difficult part of the investigation proved to be the finding of reliable methods for analysis of the electrolyzed solution. It was thought that the chemical compounds which would be formed in the electrolyzed solution would be: (a) potassium sulphocyanate (KCNS); (b) potassium cyanate (KCNO); (c) potassium sulphate (K₂SO₄); (d) potassium hydroxide (KOH); (e) sulphur dioxide (SO₂); (f) potassium sulphite (K₂SO₃); (g) potassium cyanide (KCN); (h) carbon dioxide (CO₂). Methods for the determina-

tion of these compounds in the presence of each other were accordingly investigated.

METHOD FOR CYANATE (CNO)

1. The methods of Paterno and Pannain,³ which are given below, were first investigated:

1. To a 10-c.c. sample add a known excess of standard silver nitrate solution. Dilute to 100 c.c. and filter. In 50 c.c. of the filtrate determine the excess silver nitrate by Volhard's method. The AgNO₃ added, minus that found in the filtrate, gives the amount consumed by the cyanide, cyanate, carbonate and hydroxide, or anything else precipitated by AgNO₃ in neutral solution.

2. To a second 10-c.c. sample add a known excess of AgNO₃ and an excess of acetic acid. Dilute to 100 c.c. and filter. In 50 c.c. of the filtrate determine the excess AgNO₃ as above. The difference between the amounts of AgNO₃ used in each case is consumed by the precipitation of AgCN and AgCNO.

3. To a third 10-c.c. sample add a known excess of silver nitrate and an excess of dilute nitric acid. Dilute to 100 c.c.. In 50 c.c. of the filtrate determine the excess AgNO₃ as above. The difference between the AgNO₃ consumed in each case is used in the precipitation of KCN. The AgNO₃ consumed in (2) minus that consumed in (3) is the amount of AgNO₃ used in precipitating AgCNO.

In order to test the accuracy of this method when used with dilute solutions, a series of experiments was conducted, using a solution containing 0.001 gram of KCNO per cubic centimeter. This solution was made up by weight from Merck's C. P. potassium cyanate.

Series 1.—10 c.c. of KCNO solution were taken in each case, and amounts of AgNO₃, varying from 5 to 40 c.c., were added. The neutral solution was diluted

TABLE II.

	cc. KCNO Sol Taken	cc. AgNO ₃ Added	cc. Acetic (1-1)	cc. KCNS Required	Grams KCNO Present	Grams KCNO Found	Per Cent Indicated
Series 1	10	5	None	2.0	0.01	0.006449	64.49
	10	5	None	2.2	0.01	0.008408	84.08
	10	10	None	6.1	0.01	0.008945	89.45
	10	10	None	6.6	0.01	0.009249	92.49
	10	15	None	10.9	0.01	0.0104324	104.32
	10	20	None	15.6	0.01	0.010383	103.83
Series 2	10	25	None	20.1	0.01	0.010926	109.26
	10	30	None	24.7	0.01	0.011185	111.85
	10	40	None	33.6	0.01	0.010821	108.21
	10	5	None	1.9	0.01	0.009457	94.57
Series 3	10	10	None	6.3	0.01	0.010241	102.41
	10	20	None	10.7	0.01	0.011214	112.14
	10	25	None	15.1	0.01	0.012108	121.08
	10	30	None	23.8	0.01	0.014185	141.85
Series 4	10	40	None	32.9	0.01	0.014910	149.10
	10	5	5	3.8	0.01	0.005811	58.11
	10	10	5	7.8	0.01	0.005123	51.23
	10	10	5	7.6	0.01	0.005811	58.11
Series 5	10	10	10	8.6	0.01	0.002368	23.68

to 100 c.c. and filtered. Fifty cubic centimeters of the filtrate were then titrated with standard KCNS solution, using ferric alum indicator.

Series 2.—Same as Series 1, except that the solution was diluted to 50 c.c. before filtering and 25 c.c. were titrated.

Series 3.—Same as Series 1, except that 5 c.c. to 10 c.c. of acetic acid were added.

The results given in Table II indicate that this method is unreliable for dilute solutions. Increasing the amount of AgNO₃ added raises the KCNO indicated. The addition of acetic acid gives results 50 per cent low. It will be noted that dilution is also an important factor.

Attention was then turned to the method of Cumming and Mason⁴ for cyanate, which is based upon the

*Professor of Metallurgy, South Dakota State School of Mines.

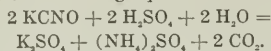
¹Personal communication—G. H. Clevenger.

²Clennell, *Eng. & Min. Jour.*, May 27, 1911.

³*Gazzette Chimica Italiana* 34 (2) 152.

⁴*Proc. of Soc. of Chem. Ind. of Victoria*, July-Aug., 1903. Also *Chem. News*, Jan. 5, 1906.

neutralization of a standard solution of sulphuric acid according to the following equation:



This method, as given by Clennell,⁴ is as follows:

"This method depends on the facts (a) that cyanates are neutral to methyl orange; (b) that, when boiled for a short time with a mineral acid, they are quantitatively converted to CO_2 (which escapes), ammonium salts and salts of the metal originally present in the cyanate remaining in solution. A known volume of the solution (which may contain carbonate as well as cyanide and cyanate) is first titrated in the cold with standard acid, using methyl orange or Congo red as an indicator. The quantity of acid to effect a change in a neutral solution of the indicator should be determined, and the proper correction applied in making the test. Having noted the point where the solution becomes neutral, a sufficient measured excess of standard acid is added beyond this point. The mixture is then boiled a few minutes to insure complete decomposition of the cyanate and expulsion of the CO_2 . The boiling may be stopped when bumping sets in. The solution is then cooled, and more indicator added if necessary. The residual excess of acid is now determined by titrating back with standard alkali. The difference between the excess acid added beyond the neutral point and the residual acid is the equivalent of the cyanate, according to the equation previously given."

In order to test the accuracy of the method, a solution of KCNO containing 4.01 grams per liter was made up. Both phenolphthalein and methyl orange were used as indicators. The results are given in Tables III and IV.

TABLE III.—USING PHENOLPHTHALEIN

cc. KCNO Sol. Taken	cc. N/10 H_2SO_4 Added	cc. KOH Required	Per Cent KCNO Indicated
10	10	1.5	\$5.94
10	10	1.2	\$8.90
10	10	1.5	\$5.94
10	10	1.9	\$0.01
10	15	6.8	\$2.91

TABLE IV.—USING METHYL ORANGE

cc. KCNO Sol. Taken	cc. H_2SO_4 Added	cc. KOH Required	Per Cent KCNO Indicated
10	10	0.8	\$2.9
10	15	6.0	\$1.00
10	15	5.9	\$2.15

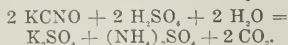
The low and erratic results obtained when using phenolphthalein were undoubtedly due to the fact that this indicator will not give satisfactory results in the presence of ammonia.⁴

Encouraged by the results obtained in the preceding series, when methyl orange was used as an indicator, a further series was run. A solution containing 1 gram KCNO per liter was made up for this series, methyl orange being used as an indicator in making the titrations. (Table V.)

TABLE V.

cc. KCNO Sol. Taken	cc. H_2SO_4 Added	cc. KOH Required	Per Cent KCNO Indicated
40	10	0.75	\$3.75
40	20	10.8	\$3.25

The value of the N/10 H_2SO_4 in terms of KCNO and CNO was calculated from the below equation:



The value of N/10 H_2SO_4 in terms of KCNO per cubic centimeter was found to be 0.004055 gram, and in terms of CNO to be 0.00210 gram.

As a further test of this method, a stronger solution

of KCNO, containing 5 grams KCNO per liter, was made up. It was found, however, that, with a solution of this strength, a blue coloration was formed when the N/10 acid was added and the solution boiled. The same result was obtained in all of many trials. At the time it was thought that, due to accident, some iron salt might be present in the solution but, after special precautions were taken and all reagents tested for iron, the same effect persisted. It is thought that the coloration is due to some complex cyanogen compound.

The method is apparently not applicable to any but weak solutions, as the blue coloration renders the titration with methyl orange impossible.

This method was adopted for the determination of cyanate in the weak solutions resulting from electrolysis. The N/10 H_2SO_4 solution employed in making the titrations was checked by the BaSO_4 method.⁵

METHOD FOR SULPHOCYANATE (CNS)

The first method tried for the determination of sulphocyanate (CNS) was a reversal of the well known iodate method⁶ for copper. Twenty cubic centimeters of the sulphocyanate solution were made just acid with HCl, then 4 c.c. of acid were added in excess. The solution was heated almost to boiling and 15 c.c. of copper sulphate solution and 15 c.c. of sodium bisulphite solution added and stirred well. The solution was then filtered through a close filter paper and washed rapidly with boiling water. The copper present in the precipitate was then determined by titrating with a standard solution of potassium iodate (KIO_3) using chloroform as an indicator. The percentage of sulphocyanate present was then computed. The copper sulphate solution used contained 64 grams of the hydrated salt per liter and the sodium bisulphite (NaHSO_3) solution contained 75 grams per liter.

This method with solutions of known sulphocyanate content gave accurate results when carefully done. However, it requires considerable time. As an improvement upon the above method, direct titration of the sulphocyanate with potassium iodate was tried. The method consisted in taking a 20-c.c. sample of the solution in a 250-c.c. flask, together with 30 c.c. of concentrated HCl and 5 c.c. of chloroform. It was then titrated direct with the KIO_3 solution.

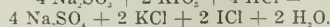
The solution of potassium iodate was standardized by means of C.P. copper foil. One c.c. was found to be equal to 0.00185 gram sulphocyanate.

In order to test this method a solution of potassium sulphocyanate (KCNS) was prepared of such a strength that 20 c.c. contained 0.0242 gram CNS. The solution from which the samples were taken contained the same substances as the electrolyte, among others SO_2 in the form of Na_2SO_3 . (Table VI.)

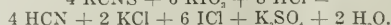
TABLE VI.

	Grams CNS Present	Grams CNS Found	Per Cent Indicated
1.....	0.02420	0.02451	101.2
2.....	0.02420	0.02484	102.5
3.....	0.02420	0.02462	101.7

It will be noted that the results were all high. This was probably due to the presence of SO_2 , which reacted with the standard iodate solution according to the below equation:



The equation for the titration of CNS by KIO_3 is given below:



⁴Chemistry of Cyanide Solns. P. 183.

⁵Analytical Chemistry. Treadwell & Hall. Vol. II, p. 434.

⁶Treadwell and Hall Analytical Chem. Vol. 2, pp. 268-370.

⁷The Iodate Method for Cu. W. W. Brostrom, E. & M. J. Aug. 1, 1914. Also Jour. Am. Chem. Soc., Vol. 30, p. 760.

The sample of KCNS solution contained 0.002044 gram SO_2 in each 20 c.c. sample. Hence $0.002044 \div 0.00715 = 0.28$ c.c. of standard KIO_3 , which should be subtracted from the amount used in the titration of 20 c.c. of the KCNS solution for CNS.

After making this correction for the presence of SO_2 , the results were as given in Table VII.

TABLE VII

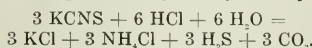
	Gm. CNS Present	Cc. KIO_3 Used	Gm. CNS Found	Per Cent Indicated
1.....	0.02420	11.95	0.02386	98.6
2.....	0.02420	11.2	0.02419	99.9
3.....	0.02420	11.1	0.02391	99.0

When this correction was applied this method checked within reasonable limits and it was, therefore, used in the analysis of the electrolyte produced by the several series of electrolyses.

METHOD FOR SO_2

The first method tried consisted in adding an excess of a solution of silver nitrate to a 50 c.c. sample of the electrolyte in order to precipitate CNS as AgCNS which was filtered out. The excess of silver was precipitated with HCl and also filtered out. The SO_2 was then precipitated in the usual way with BaCl_2 .

It was later found that KCNS does not interfere with the precipitation of BaCl_2 . When KCNS is boiled with HCl the following reaction probably takes place:



If a filter paper moistened with lead acetate is held over a beaker containing boiling KCNS solution acidified with HCl , the paper will be darkened in a manner characteristic of the action of H_2S on lead acetate. Taking these various facts into consideration, the method was modified as follows: A 20 c.c. sample of the electrolyte was made acid with 1 c.c. HCl , and boiled. The SO_2 was then precipitated with BaCl_2 as before. Using 20 c.c. samples of the electrolyte containing 0.00384 gram SO_2 , the results of Table VIII were obtained.

TABLE VIII

Cc. Sample Taken	SO_2 Present	Wt. BaSO_4	SO_2 Found	Per Cent Indicated
20	0.00384	0.0094	0.00356	100.5
20	0.00384	0.0093	0.00382	99.5

This method was, therefore, used in all subsequent determinations.

METHOD FOR SO_2

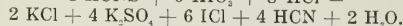
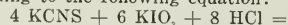
Considerable difficulty was met in finding a suitable method for the determination of the sulphite in the electrolyte. The first method tried was to treat the sample with an excess of bromine water and remove the excess by boiling. The sulphur was then precipitated with BaCl_2 and weighed in the usual way. From the weight of BaSO_4 obtained, the weight of the BaSO_3 found in the determination of SO_2 was subtracted and the remainder calculated to SO_2 . This method was found to be unsatisfactory and a method depending upon the oxidation of the sulphur in the KCNS by means of iodine was accordingly investigated.

A 20 c.c. sample of a solution containing 0.00204 gram SO_2 in the presence of KCNS was made acid with three c.c. of concentrated HCl and 10 c.c. of iodine solution added. The solution was boiled until colorless and precipitated with BaCl_2 solution. The precipitate of BaSO_4 formed should have contained the total sulphur in the solution. The weight of BaSO_4 obtained from the SO_2 determination was subtracted and the remainder calculated to SO_2 . In order to determine the accuracy of the method a series of analysis were run

upon solutions of known SO_2 content, but the results obtained were all found to be decidedly low. It was thought that perhaps the amount of iodine and HCl added were insufficient to decompose and oxidize the KCNS completely. Iodine was therefore replaced by bromine but low results were still obtained.

Another method, involving the removal of CNS by precipitation as CuCNS by boiling with CuCl solution¹⁰, was tried. It was found that, after the CuCNS had been filtered out and iodine solution added, a white precipitate came down, making precipitation with BaCl_2 impossible. The method was, therefore, discarded as being impractical.

The method finally adopted proved to be extremely simple and effective. It depended on the oxidation of the KCNS by means of potassium iodate (KIO_3) solution according to the following equation:



The method is as follows: To a 20 c.c. sample, 40 c.c. of KIO_3 solution were added, together with 1 c.c. of concentrated HCl . The solution was then boiled and the sulphur present precipitated with BaCl_2 . From the weight of BaSO_4 obtained the weight of the BaSO_3 corresponding to the KCNS present was subtracted and the remainder calculated to SO_2 .

Results obtained by the method were as given in Table IX.

	Grams BaSO_4 Obtained	Grams BaSO_4 Due to KCNS	BaSO_4 from SO_2 Grams	SO_2 Present Grams	SO_2 Indicated Grams
1.....	0.1144	0.1068	0.0076	0.00204	0.00208
2.....	0.1143	0.1068	0.0075	0.00204	0.00205

This method was used in subsequent analyses.

METHOD FOR KCN

The first method tried was as follows: To the sample was added a known excess of silver nitrate and 10 c.c. of HNO_3 (1-1). The volume was made up to 100 c.c. and the excess silver nitrate titrated with standard NH_4CNS , using a 50 c.c. sample. The amount of silver nitrate consumed by the (CN) and (CNS) was thus obtained. From this the amount previously determined to have been consumed by the (CNS) was subtracted, leaving the amount of silver nitrate consumed by the (CN). From this the weight of (CN) present was calculated.

This method, which theoretically should give good results, proved to be unsatisfactory. Results obtained with it were either very high or very low.

According to Clennell¹¹, (CN) may be titrated direct with silver nitrate in the presence of alkalis, ferrocyanides and thiocyanates and fairly accurate results obtained. The presence of KCNS and KCNO interferes but slightly unless over 1 per cent of these substances be present. In testing this method a series of 20 c.c. samples, each containing 0.00193 gram (CN), were titrated. The standard silver nitrate used was prepared by dissolving 6.525 grams of C.P. crystallized AgNO_3 in 1 liter of water.

The results obtained by direct titration were as given in Table X.

TABLE X

Cc. Sample	Cc. AgNO_3 Used	Grams CN Present	Grams CN Indicated
20	0.9	0.00193	0.00172
20	1.0	0.00193	0.00191
20	1.1	0.00193	0.00210
20	1.0	0.00193	0.00191
20	1.2	0.00193	0.00229
20	1.0	0.00193	0.00191
Average			0.00197

¹⁰ CuCl_2 solution was reduced to CuCl by means of stannous chloride.

¹¹ KIO_3 solution contained 40 grams KIO_3 per liter.

¹²Clennell. Chemistry of Cyanide Solutions. p. 4.

The method of direct titration does not appear to give absolutely accurate results but the errors shown were not sufficiently large to appreciably affect the results of this investigation. This method was, therefore, adopted for subsequent analyses.

METHOD FOR (OH)

Much difficulty was experienced in finding a suitable method for determining the (OH) present. The first method tried consisted in precipitating the carbonate in a 20 c.c. sample by the addition of an excess of $\text{Ba}(\text{NO}_3)_2$, diluting to 100 c.c. and allowing to stand, tightly corked, for an hour. The solution was then filtered and to 25 c.c. of the filtrate a known excess of silver nitrate was added and the volume made up to 100 c.c., filtered and the excess silver nitrate determined. From the amount of AgNO_3 consumed was subtracted the equivalent of the (CN), (CNO) and (CNS) previously determined. The remainder was calculated to hydroxide. The results obtained by this method could not be made to check. All the methods available for the determination of (OH) were tried out with varying degrees of success. It was finally decided to determine alkalinity instead of (OH), after the manner in which the "protective alkalinity" of working cyanide solutions is determined. 20 c.c. samples were accordingly taken and titrated for (CN) by Leibig's¹³ method with AgNO_3 to the first turbidity. Two drops of phenolphthalein were then added and the solution titrated to the colorless end point with N/10 H_2SO_4 . When a 20 c.c. sample of the solution is taken each c.c. of N/10 H_2SO_4 = 0.0280 per cent KOH. The alkalinity was recorded in terms of percentage of KOH.

METHOD FOR CO_2

The first method tried consisted in adding an excess of $\text{Ca}(\text{NO}_3)_2$ to a 50 c.c. sample of the solution which was allowed to stand in a stoppered flask for one-half hour. It was then filtered and the precipitate washed with hot water. The CO_2 in the precipitate was then determined by an alkalimeter¹⁴. According to Treadwell and Hall¹⁵, this method affords excellent results when large quantities of CO_2 are involved but with small amounts, such as were present in this case, the method was found to be inaccurate on account of the weight of the apparatus. Results obtained by this method were unsatisfactory and it has the further disadvantage of being somewhat tedious.

The following method was then tried. The CO_2 was precipitated with BaCl_2 and the resulting $\text{Ba}(\text{CO}_3)_2$ filtered out, washed and titrated with an excess of N/10 H_2SO_4 . The excess of H_2SO_4 was determined by titrating back with standard alkali solution. The method gives slightly high results, as may be seen by the following results, but the results were found to be sufficiently accurate to warrant its adoption. (Table XI.)

TABLE XI

Cc. H_2SO_4 Used	Grams CO_2 Present	Grams CO_2 Indicated
5.2	0.0111	0.0114
5.4	0.0111	0.0118
5.3	0.0111	0.0116
5.6	0.0111	0.0123

In order to test the accuracy of the various analytical methods selected, a solution was prepared containing all of the compounds which would probably be found in the solution after electrolysis. The methods of analysis previously described were used for making the

various analyses upon this solution, a 20 c.c. sample being taken for each determination. (Table XII.)

TABLE XII.

Compound	Grams Present	Grams Found	Percentage Indicated
CNS	0.02420	0.02401	99.1
CNO	0.01690	0.01660	87.2
CN	0.00190	0.01970	102.0
SO_4	0.00380	0.00380	100.0
SO_2	0.00200	0.00205	100.9
* CO_2	0.01110	0.00117	105.4

Results of Electrolyses of Alkaline Solutions of KCNS:

The electrolyzing cell used throughout this investigation was a rectangular glass jar, 7 in. x 7 in. x 10 in., having a capacity of 7 liters. The electrodes used were two graphite plates 11 in. x $2\frac{3}{4}$ in. The distance between the electrodes varied from $3\frac{1}{2}$ in. to 4 in. The submerged portion of the electrodes measured $7\frac{1}{2}$ in. x $2\frac{3}{4}$ in. The solution electrolyzed contained approximately 60 grams of potassium sulphocyanate (Merck) per liter. The exact percentage, as well as the voltage and current in amperes, is shown in Tables 13 to 17, giving the results.

TABLE XIII.—ELECTROLYSIS No. 1.

Time	Voltage 2.1.		Current 0.5 ampere.		No alkali added.		Per Cent	
	Per Cent CNS	Per Cent Cent CN	Per Cent Cent SO ₄	Per Cent Cent OH	Per Cent Cent CNO	Per Cent Cent CO ₂	Per Cent Cent SeO ₂	
Original solution.	0.601	None	None	None	0.022	None	None	
End of 1 hr.	0.595	None	0.004	None	0.022	None	None	
End of 2 hrs.	0.593	None	0.006	None	0.021	None	None	
End of 3 hrs.	0.590	None	0.008	None	0.021	None	None	
End of 4 hrs.	0.585	None	0.011	None	0.020	None	None	
End of 5 hrs.	0.581	None	0.015	None	0.020	None	None	

The solution at the end gave an acid reaction. It is seen that under this condition the CNS is broken up and forms sulphate, but no regeneration of (CN) takes place.

TABLE XIV.—ELECTROLYSIS No. 2.

Time	Voltage 2.7 volts.		Current 0.5 ampere.		Alkali added.		Per Cent CNS	Per Cent CO ₂	Per Cent CNS
	Per Cent CNS	Per Cent CNS	Per Cent CNS	Per Cent OH	Per Cent CO ₂	Per Cent CNS			
Original solution.....	0.540	None	None	0.560	0.019	0.014	None	None	None
After 1 hr.....	0.537	0.003	0.003	0.360	0.021	0.016	None	None	None
After 2 hrs.....	0.534	0.003	0.003	0.353	0.020	0.014	None	None	None
After 3 hrs.....	0.533	0.003	0.008	0.353	0.020	0.018	None	None	None
After 4 hrs.....	0.532	0.003	0.010	0.353	0.020	0.014	None	None	None

This electrolysis was run under the same conditions as No. 1 and was intended to show the effect of having the solution alkaline. In this case there is a small amount of (CN) formed, accompanied with a slight decrease in alkalinity.

TABLE XV.—ELECTROLYSIS No. 3.

TABLE XV.—ELECTROLYSIS NO. 90.									
Voltage 5.4. Current 1.8 amperes. Alkali added.									
Time	Per Cent CNS	Per Cent CN	Per Cent PO ₄	Per Cent OH	Per Cent CNO	Per Cent CO ₂	Per Cent SO ₂		
Original solution.	0.485	None	None	0.280	0.003	0.008	None		
After 1 hr.	0.481	0.003	0.025	0.262	0.006	0.005	None		
After 2 hrs.	0.470	0.011	0.045	0.246	0.005	0.005	None		
After 3 hrs.	0.457	0.013	0.057	0.230	0.005	0.005	None		
After 4 hrs.	0.441	0.016	0.067	0.207	0.006	0.005	None		
After 5 hrs.	0.438	0.019	0.084	0.190	0.007	0.006	None		

It will be noted that, with the increase in voltage, the formation of (CN) is much greater than in Electrolysis No. 2. The formation of SO_2 is also largely increased. The CNO and CO_2 remain almost stationary.

TABLE XVI.—ELECTROLYSIS No. 4.

Time	Voltage 7.0.		Current 3.05 amperes.		Alkali added.			
	Per	Per	Per	Per	Per	Per	Per	
	CNS	CN	SO ₄	OH	CNO	CO ₂	SO ₂	
Original solution.	0.441	None	None	0.400	0.007	0.018	None	
After 1 hr.	0.414	0.008	0.031	0.384	0.006	0.020	None	
After 2 hrs.	0.410	0.016	0.053	0.361	0.009	0.020	None	
After 3 hrs.	0.394	0.021	0.083	0.330	0.010	0.016	None	
After 4 hrs.	0.365	0.025	0.120	0.300	0.008	0.022	None	
After 5 hrs.	0.360	0.027	0.151	0.266	0.008	0.018	None	

It will be noted that, with the higher voltage, the increase in CN is proportional to the decrease in CNS and KOH. The CNO and CO_2 remain stationary, as in electrolysis No. 3.

*The method used in this determination, and in subsequent determinations, is a slight modification of the one previously given. It is as follows: In a 20 cc. sample the carbonate present was precipitated with $\text{Ca}(\text{NO}_3)_2$ and the filtrate made neutral. A known excess of N/10 H_2SO_4 was added and the solution boiled. The excess acid was then titrated back with N/10 alkali, using phenolphthalein as indicator.

¹³Glennel. Chemistry of Cyanide Solutions, p. 4.

¹⁴Analytical Chemistry. Treadwell and Hall, vol. 2, pp. 293-295.

¹⁵Analytical Chemistry. Treadwell and Hall, vol. 2, p. 295.

TABLE XVII.—ELECTROLYSIS No. 5.

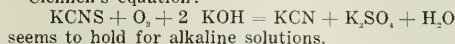
Voltage 5.9. Current 4.0 amperes. Alkali added.							
Time	Per Cent CNS	Per Cent CN	Per Cent SO ₄	Per Cent OH	Per Cent CNO	Per Cent CO ₂	Per Cent SO ₂
Original solution	0.494	None	None	0.361	0.007	0.008	None
After 1 hr	0.474	0.013	0.057	0.328	0.005	0.009	None
After 2 hrs	0.454	0.021	0.089	0.300	0.007	0.008	None
After 3 hrs	0.436	0.029	0.122	0.224	0.008	0.008	None
After 4 hrs	0.416	0.036	0.158	0.174	0.008	0.007	None
After 5 hrs	0.398	0.042	0.192	0.146	0.008	0.007	None

Conclusion

When an alkaline sulphocyanate solution is electrolyzed the decomposition products are KCN and K₂SO₄.

There is little or no KCNO, CO₂ or SO₂ formed.

Clennell's equation:



When a neutral sulphocyanate solution is electrolyzed, HCN is given off as a gas and the solution becomes acid.

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Blast Furnace Operation

Casting and Flushing the Furnace, Blowing In, Blowing Out, and Banking

BY J. E. JOHNSON, JR.

In earlier articles the descent of the iron and slag into the hearth has been described. One of the important factors in operation and one not always easy to accomplish is their removal at the proper time and under strict control.

In the earlier furnaces no attempt was made to withdraw the slag separately from the iron, and at charcoal furnaces this practice is still followed in some cases. The cinder comes out of the iron notch at casting time and at no other time.

The introduction of coke and anthracite as furnace fuels brought about much larger slag volumes, as already described. These resulted in causing the hearth to fill up much more rapidly, and when outputs had reached a point only a fraction of what they are to-day it was found that the slag rose around the tuyeres and impeded the driving of the furnace, causing increased blast resistance and covering the slag so as to impede its circulation. This resulted in providing a separate outlet for the slag at a considerably higher level than the tapping hole for the iron, but well below the level of the tuyeres, so that by draining off the slag down to this point it would be removed from the tuyere zone and its bad effect on the operation of the furnace eliminated.

The earlier cinder notches were a sort of low doorway, a foot or two wide by 3 or 4 in. high, with a water-cooled lintel or "tymp" above it, which could only be closed with clay balls driven in with a stopping hook. This operation involved taking the blast off the furnace at each flush, because the sparks and flame blown out the opening not only made it virtually impossible for a man to work in front of it, but also blew away the clay stop as fast as it could be put in. This practice involved taking the blast off the furnace from one to four times between casts. This reduced the output, disturbed the regular action of the furnace, particularly the settling of the stock, and necessitated much work.

About forty years ago Mr. F. W. Lürman of Germany invented the water-cooled cinder notch which is now practically in universal use. By a gradual process of evolution since that time this has now developed into a water-cooled monkey, which is exactly like a tuyere in its general outline and appearance, but much smaller.

This is supported and protected by a larger water-cooled bronze casting, known as the cinder cooler, which is practically identical except in size with the tuyere cooler. Frequently this in turn is protected by a still larger cooler extending back to the outer wall of the furnace, which may be either of the iron-pipe coil construction or a still larger bronze casting, generally the former.

The cinder notch, as it is called—that is, the monkey—is closed by an iron plug on the end of a long iron rod, which serves as a handle. This piece, called the "bot," acts as a plug and also as a chill. When a blubbering or sputtering of the stream of cinder indicates that the blast is blowing out above it, and therefore that its level is down to that of the notch, the furnace "keeper" takes the bot by its long handle, puts it through the cooler and up to the base of the monkey, then gives it a quick thrust and holds it for a few seconds. The cold bot and the water-cooled walls of the monkey chill the thin skin of slag between them and instantly make a perfect joint. The bot does not project through the cinder monkey, and is virtually not exposed to the heat except on its extreme end, and even that is chilled over by the cooling action of the adjacent monkey. Consequently this bot lasts quite a long time. It is generally allowed to remain in the monkey until the time for the next flush, when it is pulled out with a ring and wedge. A sharp steel bar is inserted into the hole which it left and the scull is broken through either by poking with the bar or by a couple of blows on the outer end of the latter with a sledge. By having the handle of the bot bent it can be operated by a man standing, not directly in front of the cinder notch but well to one side, and consequently to some extent out of danger from flame and shots of slag. A shield can be provided where necessary, from behind which the bot can be operated without the keeper's exposing his face to injury.

It will be seen that by this method the necessity of taking the blast off the furnace at each flush is entirely eliminated, while the labor incident to opening and shutting the slag notch is reduced to an insignificant fraction of what it was by the old method. Moreover, by the use of these water-cooled apertures the slag can be allowed to run for an indefinite time without cutting out the hole, whereas under the old system the hole gradually became enlarged by the blowing of the blast through it, so if the cinder ran too long it was difficult to stop.

Coke furnaces are now flushed from two to five times before cast and virtually without any labor. In very recent months an apparatus has been introduced at the Edgar Thomson furnaces whereby the bot is controlled by means of a cylinder operated by steam or compressed air. The bot is so held that it must enter the monkey properly without being guided by hand, and consequently the keeper can shut the slag notch from any desired distance by simply opening the valve controlling the cylinder. This eliminates absolutely the danger to the operator from shots of slag, which in time gone by have caused many slight burns and occasionally the loss of an eye.

The slag cannot be all removed by flushing, because the cinder notch must be located at a safe height above the top surface of the molten iron at its highest point, so in the case of a delay of an hour or two in casting the iron will not rise high enough to come in contact with the monkey and cinder cooler, therefore there must in normal operation be an appreciable height between the top surface of the iron and the cinder notch which must be filled with slag before any can be tapped out.

The reason for keeping the cinder notch well above the iron is that while water-cooled bronze is almost absolutely safe against the cutting action of the stream

of molten slag, it has only a slight resistance to the cutting power of a stream of molten iron, and, the cooler walls being very thin, if the iron does cut the bronze it immediately runs into the water-cooled cavity and a terrific explosion inevitably results.

The violence of these explosions, which is almost beyond belief by those who have not seen their effects, was well illustrated by one case which I saw: a piece of a bronze cinder cooler which exploded when it was cut by iron was picked up within so few seconds of the explosion that it was still hot at a distance of 300 yd. or more from the furnace, and in such a location that it could not have been thrown directly from the cinder cooler, but must have ricocheted from some other object. To avoid such accidents it is therefore very necessary to have the cinder notch set at such an elevation that iron will never in normal operation have an opportunity to run out through it. Moreover, if the cinder notch is set too close down to the surface of the molten iron the furnace will "lift" iron through the notch at flushing time, and this iron running along under the cinder will very frequently be entirely lost, constituting a very serious loss of product.

The reason why charcoal furnaces, especially those working on rich ores, sometimes run without flushing is twofold: First, the slag volume is relatively small and so does little harm; second, since it is impossible to remove all the slag through the cinder notch the smaller the total amount the larger the proportion of it which must remain in the furnace even after flushing, so that it is sometimes not worth while to flush at all.

Casting the Furnace

As the molten iron descends into the hearth its level gradually rises. I have already described the danger to which water-cooled bronze parts are exposed by the cutting action of molten iron. When the iron does not run across them, but only lies in contact with them, the danger is much less, but it is still great, and, as we have just seen, the cinder notch is located so that in proper operation the iron is withdrawn before it reaches the level of the cinder cooler. The capacity of the hearth up to a safe distance below this point is a measure of the quantity of iron which should be allowed to gather in it, and this in conjunction with the hourly product of the furnace is the fundamental controlling factor of the frequency with which the furnace must be cast. (We speak now of casting the furnace; presumably the original phrase was casting the iron, in the sense of throwing it or discharging it from the furnace, but the former term is in universal use among furnacemen.)

Until within quite recent years it was the almost universal custom to cast four times a day, but with the increase in outputs which came with the Duquesne Revolution the capacity of the hearths of existing furnaces was not sufficient to hold the increased output for this length of time, and furnaces were cast five, six, and even eight times a day. There is, however, a certain amount of labor involved in preparing for each cast and cleaning up after it. The iron runners have to be made ready before and generally cleaned after cast, the skimmers must be set, the iron trough grouted, and various other practical but nevertheless imperative details attended to before and after this important rite can be performed; therefore the more casts the more work, and the increased outputs were soon followed by larger hearths to give greater storage capacity for iron. Perhaps it would be at least partly correct to say that the larger hearth made the increased output possible, and after a certain point was reached this was true.

In addition to the increase in diameter the depth of the hearth below the tuyeres was increased so as fur-

ther to increase its capacity, and this practice has now so far developed that H. A. Brassert has spoken of the possibility of only casting three times a day on some furnaces, and declares that even this number may be reduced.

Personally I believe that the reduction in labor by reducing the number of casts per day below four is less than the increased risk of handling the largely increased quantities of iron, because the results of accidents occurring when the furnace is full of iron are correspondingly more serious. Moreover, while modern furnaces are provided with sufficient blowing power to make their tonnage even though there be considerable quantities of cinder up around the tuyeres, it is a matter beyond all doubt that in the older practice with poorer blowing engines the driving of the furnace would always drop, and the blast pressure would always rise when the cinder rose around the tuyeres. The action of the slag in gathering on the coke and preventing access of the air to it can scarcely be denied, and I cannot help but feel that the more the slag rises above the tuyeres in streamers blown by the blast, as already described, the greater will be its action in covering the coke and preventing the proper action of the blast upon it in the lower regions of the bosh, and the further the top of the zone of combustion will be forced upward with consequent possibilities of derangement.

It seems to me desirable, therefore, to keep the hearth as free of slag as possible, and this can most easily be done by keeping down the level of the iron on which the slag floats. Further, I believe that the advantages of having less than four casts do not compensate for the possible dangers and disadvantages. It is impossible to obtain the benefits of a water-cooled aperture through which to cast the iron in the same way that we do the slag, for the reason that there is no metal which is not cut by a current of iron running at high velocity, no matter how thorough the water cooling, and as I have already explained, the results of cutting such cooling members by molten iron are likely to be catastrophes rather than accidents, involving certainly many hours of delay on the furnace, with possibly great physical damage to it, and, worst of all, almost certainly, serious injury or death to the workmen around the front of the furnace. We are, therefore, compelled to use refractory materials, and in common practice there is only one used for a base, fireclay, though other substances may be mixed with it. This is rammed into the tapping hole at the conclusion of each blast by a method which may be best described in advance of describing the operation of casting itself, because the two are so interdependent that to say which comes first is like answering the old riddle, "which comes first, the hen or the egg?" At the conclusion of cast we have a hole 3 to 6 in. or more in diameter, but preferably only 3 or 4, leading inward and downward into the hearth of the furnace, through which the contents of the latter have just been discharged.

It would seem at first sight remarkable that the hole should lead downwardly into the furnace, since it would seem that the furnace could not drain itself properly through a hole so located, and it would not except for the pressure of the blast which, as we have seen in an earlier chapter, is equal to that of a column of iron several feet in depth, and which, therefore, lifts the iron and slag through the tapping hole, the latter acting as an inverted siphon. When the blast is taken off the remaining molten material drops back through this hole into the hearth and out of the way, so that there is no dribbling of molten iron through the tapping hole while it is being stopped.

Until a few years ago it was the universal custom to

stop the tapping hole with balls of fireclay driven in by a stopping hook operated by hand labor, but as pressures and outputs rose, resulting in a greater depth of molten metal in the hearth, and a greater pressure of blast on top of it, it became increasingly difficult to drive the clay in far enough by this means to prevent this combined pressure from forcing the iron out through it, and once a trickle of this kind started it was rapidly enlarged by its own cutting action until it was soon beyond control, constituting a "breakout at the tapping hole" which, while less serious than one through the hearth jacket, was a mishap of no mean proportions, particularly if it occurred before the iron trough was grouted, the skimmer set and the sand beds made up ready to receive the iron, these representing general practice at that time.

About twenty-five years ago the late Samuel Vaughan, then superintendent of blast furnaces at Johnstown, Pa., in order to overcome these disadvantages invented the "mud gun." This consists of a steam cylinder carrying in front of it a smaller cylinder much after the general style of a direct-acting steam pump, the pistons of both cylinders being connected to the same rod. The forward or mud cylinder is open at its front end, provided with a nozzle some 3 or 4 in. in diameter, the cylinder being 7 or 8, depending upon the size of the furnace. A hole is provided through the mud cylinder just in front of the piston when the latter is drawn back into its farthest position. This front cylinder is loaded with tempered clay, plastic but quite stiff. At the conclusion of cast this whole apparatus, which is mounted on a small jib crane hung to one of the furnace columns and connected to the steam by swing joints or hose connections, is swung around in front of the furnace, the nozzle of the mud cylinder is entered into the tapping hole, then a pair of dogs or cams on a shaft running across the two front columns take hold behind two lugs on the mud cylinder, and by the rotation of the shaft force the nozzle down hard into the tapping hole. The hand-operated valve which controls the steam supply is quickly opened and the whole charge of clay is shot into the tapping hole. After allowing it to stand for a few seconds the piston is withdrawn and clay balls fed by hand into the opening at the rear of the mud cylinder. These in turn are rammed down to place by throwing on steam and driving forward the steam piston; the mud piston acts as a combined piston and steam hammer, being used not only to push but to pound the clay down into the hole.

As at first designed the shaft which holds the gun to place was operated by man power through a lever, but a few years later Felix McCarthy of Pottstown applied to this purpose a vertical cylinder fastened to one of the furnace columns, and by simply throwing steam on this cylinder the mud gun, once in place, was held securely without the necessity of any men to hold it, the only men required being the keeper to operate the hand valve of the steam cylinder on the mud gun, and a helper to feed clay balls into the mud cylinder.

With this powerful apparatus there is virtually no limit to the amount of clay which can be forced into the front of the furnace, nor to the solidity with which it can be driven in. The danger from kicks of iron and slag due to the contact of the wet clay balls was very great in the days of hand stopping, men were frequently burned by the iron stopping hook driving through the clay stop and striking molten iron, or by some of the other minor explosions which are almost universal coincidences of the contact of wet material of any kind with molten iron and even molten slag. This danger is entirely eliminated by the mud gun, as is the terrific manual labor of driving clay into the front of the fur-

nace while standing right over the top of the iron trough heated to a white heat by the iron and cinder passing through and remaining in it.

Moreover, this invention has done more to make it easy to cast the furnace than all the other attempts along that line put together. In the days of hand-stopping the clay necessarily became more or less intermixed with iron and slag in the tapping hole, and these, (particularly the iron) enmeshed in the clay, becoming cold, made exceedingly difficult drilling. Then, too, owing to lack of power, the tapping holes were very short, only a few inches in length, like an irregular hole punched through a very thin wall, and the result of this was to permit the iron to come very close to the outside of the hole, and the resulting matted mixture of clay, iron, and slag was burned in many cases to a hardness almost beyond that of the drills. By the use of the gun two things are accomplished: First, sufficient clay to fill the tapping hole solid full is thrown into it almost instantaneously, and with such power as to sweep all liquid material before it, the clay acting almost like a solid piston flowing into the hole. This prevents the intermixture of the iron and slag with the clay, and eliminates the difficulties which arise from that condition; second, the hole is carried so much longer that it reaches well toward the center of the furnace. In the old practice the tapping hole was at the bottom of a sort of pocket in the hearth opposite the front of the furnace, and was the farthest point away from the heating influence of the tuyeres. With the use of the gun this pocket is entirely eliminated; so much clay is forced into the front of the furnace as to put the inside end of the tapping hole inside the line of the hearth proper. The consequence is that instead of having to drive or drill through a chilled convex surface of exceedingly hard material we have now only to drive through a concave surface of material almost at a white heat, and not hard because free from iron and slag, although by its thickness mechanically strong enough to resist the pressure. This being a pure refractory clay, offers more resistance to heat than it did when intermingled with fusible substances like iron and slag.

In very recent years two or three apparatus have been designed whereby the mud gun can be thrown into the tapping hole by purely mechanical means operated by a steam cylinder, so that the furnace man, standing at a distance, can turn steam on the control cylinder, throw the gun into the tapping hole, hold it there, and then turn the steam on the gun cylinder proper, throwing the clay into the tapping hole. The result is that this operation can be done even when the iron is running full force from the furnace. This was impossible in the days of hand-stopping, and exceedingly difficult and dangerous with the mud gun when the latter was swung in and locked fast by hand, though I have known cases in which furnace men of unusual nerve and presence of mind, seeing something about to go wrong with the disposition of the iron, such as filling all the ladles available before the conclusion of the cast, or the like, have succeeded in throwing the gun into the hole and stopping it with the iron running full force. With the modern mechanically controlled apparatus this can be safely done as a regular practice. The consequence is that the blast does not require to be taken off the furnace, with the consequent disturbance in the rate of settling of the latter, and casting instead of definitely ending each period of furnace work becomes merely an occasional incident in its steady and continuous operation.

Opening the Tapping Hole

This operation was carried on until quite recent years by drilling with hand drills. Sometimes one man held

and guided a chisel bar while his helpers drove it with sledges virtually in the way that old-fashioned drilling for mining was done, or in other cases a gang of men from four to ten or twelve were put on a long churn drill whose weight was sufficient to make it both drill and hammer in one. Drilling was carried on until the temperature and the physical condition of the material at the bottom of the hole showed that the iron was very close, when the drill was generally removed and a bar driven by a sledge to break the remaining skull if there were any. In many cases with churn drilling the drill broke through the skull and the iron came without the necessity for driving the bar.

This was the practice in the days of pig beds and hand labor for everything. Now the number of men on the furnace is not sufficient to operate one of these huge churn drills, while the easier drilling produced by the use of the mud gun as just described has made these powerful blows unnecessary, and the hole is drilled out either by light sledging on a small chisel bar, or else a clay auger driven by a compressed air or electric motor is used. This is held and fed down into the hole by two men. When they see that they are close to the iron the auger is removed from the hole and the skull broken by a steel bar driven by a hammer as just described. This reduces the labor of casting the furnace to a fraction of what it was in the older practice, even with a regularly working furnace; when the furnace was working irregularly under the old conditions there was never any telling how much time or labor would be required to get the tapping hole open. The red-hot material composed, as I have indicated above, of clay, iron, and cinder could be drilled in to a certain point at which its temperature was so high as quickly to dull the edge of the drills, while it was still so hard and at the same time so tough that to drive a bar through it was often an impossibility. Consequently, it was not uncommon thing to see furnaces require two, three, and four hours to drill open the tapping hole, which should have been done when things were working properly in ten or at most fifteen minutes.

This drilling with a churn drill is by no means a gentle exercise; a few minutes of it will temporarily exhaust even a powerful gang of men, so in a case of this kind two relays of men must be provided, while the drills are dulled so quickly that two crews of blacksmiths are not always able to keep crews supplied with drills. Of course, these frightful conditions only occurred semi-occasionally, but the impression which they created when they did come was a lasting one.

The labor and expense entailed by these conditions is the least serious part of the difficulty; the design of the furnace as I have above indicated is such that the well or hearth will hold the iron made between two consecutive casts with a safe margin. At the end of an hour this margin, in the old days at least, was likely to have disappeared. The iron would then be up to the cinder notch, while the cinder would be well above the tuyeres, and only kept out of these by the pressure of the blast. The stopping of the blowing engines would have filled the blow pipes and the penstocks and cause hours of delay, yet to continue blowing constantly increased the height of the iron and cinder. Up to a certain point it was considered safe to open the cinder notch and flush the cinder; after that it was certain that the iron would be above the cinder notch, and the question was whether to take the risk of the damage that the iron would almost certainly cause by rising around the tuyeres, or risk the danger of flushing it through the cinder notch with the likelihood of cutting the monkey or the cooler and producing a disastrous explosion. It was one of those conditions in which it

was out of the question to stop, and yet to go on seems like destruction. There was nothing for it except, perhaps, to slow the engines down as far as was safe and to hope that the attempts to open the tapping hole would succeed before the catastrophe came, whatever its form might be.

Owing to the vastly better conditions, and the almost perfect control which the mud gun gives us of the tapping hole these bad hours are now very generally a thing of the past. I am sure that no one who has ever been through the experience will regret this fact.

Blowing In

The blast furnace is essentially an apparatus which operates not for days nor weeks, but literally for years at a time. It is virtually impossible to operate it at all except on an absolutely continuous basis. The reason why this is so, while not difficult to understand, is not exactly self-evident, and a brief explanation may not be amiss.

We have seen that fundamentally the operation of the furnace consists in maintaining a continuous downward current of solid material which starts in solid at the top and comes out molten at the bottom, and an opposite upward current of gases which attain their maximum temperature a fraction of a second after they enter the furnace, and cool off progressively as they rise through it, being discharged at the top at a temperature lower than that of the waste gases from even the best boilers, sometimes down to 200 deg. Fahr. These materials exercise a counter-current effect, both physically and chemically, upon one another throughout their passage. This means that the condition at any point in the blast furnace is the result of a floating equilibrium between the heating and reducing action of the ascending gas and the cooling and oxidizing action of the descending solid at that point.

In good practice the conditions at any given zone are practically constant throughout for an almost indefinite time, but the conditions in the individual particles of matter change rapidly from second to second in the case of the gas, and from hour to hour in the case of the stock, and each of these exercises an effect upon the other. For instance, let us suppose that the top gases are discharged from a given furnace at 400 deg. Fahr.; now if we go down a short distance we shall reach a point where these gases are 1000 deg. They are cooled from this temperature down to 400 by the action of the incoming stock, which they pass on their way up. On the other hand, the stock entering at, say, 70, descends to this point, and in so doing is heated up, let us say, to 800 deg.

If the operation be regular and normal the gas will always be about 1000 and the stock always about 800 at this point, but suppose that we ceased to fill the furnace regularly and continuously, then the surface of the charge descended to this point. Obviously conditions below this would be just the same, but the conditions above would be very different. The descending stock becomes heated, but without the addition of further charges the temperature of the gas rises steadily until when the surface of the stock column reaches our chosen zone the gases are obviously passing off at 1000 deg., there being now no stock above this zone (at which they reach this temperature) to cool them any further. Obviously the heat in the gas from 400 to 1000 deg. is gone, permanently lost as far as the furnace is concerned. Now if we begin charging against the stock which should reach this zone with a temperature of 800, reaches it instead with a temperature of 70, and is behind its schedule by as many hours as it takes in normal operation for a charge to descend to this zone,

while the heat which should have raised this fresh charge to 800 is, as we have seen, lost, and has left the furnace cooler.

The result is that this charge has had several hours less treatment for its reduction and has received much less heat than it should. If the zone to which it fell when charged is not down too far, that is, if the stock line has not been allowed to settle too far, if, in furnace parlance, the furnace be not too far down, and if there be a surplus of heat in the upper part of the furnace, as there generally is in coke practice, then the lost time and heat may be made up; but the further down the furnace is the more certain it becomes that this will be impossible and that this charge and those immediately following it will reach the hearth improperly prepared and that the regular operation of the furnace will be upset by this condition, the seriousness of the derangement being in a general way proportional to the amount of time these charges have lost.

We can carry this supposition a step further. Suppose that the top surface of the stock were permitted to descend to the level of the top of the bosh? Obviously the gas would pass off at a temperature of 2700 or 2800 deg., representing a very large proportion of all the heat developed, and if the furnace were driven at the same rate any stock which entered at this point would reach the hearth in a very short time in such a completely raw condition as to make impossible the production of iron from it.

If we carried the process a step further, and allowed the top of the stock to descend to the tuyeres, obviously the furnace would be virtually out of commission, the quantity of heat carried off by the gases would have been so great, and the time permitted for the absorption of heat by any incoming charge would be so small, practically zero, that we should have nothing but raw stock in the hearth of the furnace if we charged at such a time. Now suppose we reversed this process and filled the furnace up completely just as though it were in regular operation, and let us suppose for convenience sake that this operation could be done instantaneously. Instead of having a furnace full of material in all the stages of reduction and heating, from nothing up to completeness in both respects, we should simply have a receptacle full of cold material, and while the heat generated by the combustion of the coke in the charges at the tuyeres would warm it up it would obviously be impossible for this amount of heat, without the assistance of that of the gases which had gone before, to complete or even to come anywhere near completing the smelting operation.

This represents in a rough way the conditions which we have on blowing in a furnace. We fill it necessarily with cold stock from bottom to top, and then put fire in at the tuyeres and put on the blast. The material in the bosh instead of being molten is cold, and if we had a burden of the ordinary kind on the furnace it is obvious that we should never get it to the liquid condition so that we could remove it, to say nothing of reducing the iron contained in the charge.

Moreover, there is another large factor which exercises a precisely similar effect. The walls of the furnace weigh many hundreds of tons, and the interior surfaces of these when in operation are at the same temperature as the zone of the furnace which they inclose, and while the outer portions of the walls are not so hot, still the amount of heat contained in the walls in normal operation is enormous, it is probable that it represents the thermal value of the coke burned for a considerable fraction of a day. When blowing in these walls, of course, are perfectly cold, and it is impossible for the different zones of the furnace to acquire

their proper temperature without simultaneously raising that of the walls at these zones to the same point.

In blowing in the furnace to overcome this condition, therefore, we must charge a great quantity of fuel without any burden whatever. This mass of fuel fills the furnace up to a considerable portion of its height, probably in ordinary practice from one-fourth to one-third. It is clear that when this has burned away, and the material above it reaches the tuyeres, it will have had the benefit of the heat in the gas coming from this great mass of fuel, and that it will have been several hours in its descent while this mass of fuel is burning away. Such superincumbent portions, therefore, will have a vast advantage in time and temperature over the initial coke at the tuyeres. In practice we take advantage of this condition by putting on a very small amount of burden, with an extra large coke charge, two or three times the normal size, and then very gradually increase the burden and decrease the coke charge until finally the furnace is filled. The rate of driving while blowing in is very slow, for reasons to be given later, and this extra time which this gives especially to the upper portions of the charge, combined with the excess fuel, finally brings the different zones approximately to the temperature which they should have in normal operation, and the furnace then begins slowly to produce iron.

After the heavy blank of coke in the bottom occupying, perhaps, 25 to 35 per cent of the total volume of the furnace, according to the best judgment of the manager, has been charged, the burden is gradually increased until at the top it reaches a ratio of one to one; that is, about 1 ton of ore to 1 of coke, which is virtually half of the burden in regular operation. After lighting and blowing for several hours cinder appears and is flushed, and after twelve to twenty hours, according to the conditions and the judgment of the manager, enough iron accumulates to make it worth while to cast; during this interval the furnace is being driven very slowly, and as it settles is filled with charges slowly increasing.

After the first cast the furnace has approached so much more closely its normal conditions of temperature in the different zones that the burden may be increased more rapidly, the only guide being the indication of each cast as it is made, the appearance of the cinder, and the general conditions in the hearth as determined by looking into the tuyeres, but the furnace man who is satisfied with the way it is progressing, knowing that with normal progress each cast will be hotter than the next, increases the burden in advance so as to prevent making too much high-silicon iron. Where the practice is well standardized, and where there has been previous experience in blowing in with the same materials, it is possible to bring the furnace down on irons of the desired analysis at the first cast, and to increase the burden as needed so as to make nothing else during the blow in.

The tendency in recent years has been to shorten very much the period required in older practice to bring the furnace to normal operation.

Leaving the question of burdening we turn toward the next most important question, that of the volume of wind at the different periods of blowing in. This must be very much smaller than the normal blast blown in the furnace in normal operation for two reasons: First, to allow the effect of time to replace in some measure the deficiency in exposure to heat from which the materials first charged suffer, it being obvious that the longer these are exposed to the rising temperature due to the gradually increasing heat of the furnace the more nearly will they reach the condition they should have

at the different zones; second, the walls of the furnace are cold, as already described, and time must be allowed for these to heat up, and the blast must be encouraged to travel up them by the use of short tuyeres rather large in comparison with the quantity of blast blown because if relatively high penetration be used, especially with the open mass of coke in the hearth and bosh, the tendency of the blast is to travel to the center of the furnace and to pass up through this region like a chimney, leaving the walls relatively cold. Then as the slag begins to form it runs down, and striking on the sloping surfaces of the bosh is chilled there and so builds up, in some instances forming a shelf-like structure on the bosh walls, which is nearly if not entirely fatal to the success of the campaign being started.

I knew of one case in which a furnace was blown in on a very large volume of blast for its size, and this was blown through a small number of tuyeres, which gave excess penetration. The furnace worked so badly that at the end of a week it was blown out. When its operators went inside to see what the conditions were they found a shelf built on the bosh walls. The opening between the noses of the two shelves being something like 3 ft. 6 in. in a furnace whose bosh diameter was about 18 or 19 ft.

This seems almost incredible, but the facts were given me by the manager, who certainly had no reason to be proud of the performance, and there is every reason to believe that the story is authentic. The cause in this case is obvious; the high penetration drove the blast to the center and left the walls so cold that the cinder running down over them froze to them, and probably after a short time began increasing the bad effect, which was initially at the bottom of the trouble, by forcing the blast more and more toward the center.

For both these reasons then the quantity of blast used at blowing in is a small fraction of that used in normal operation, probably, in ordinary practice, about a third. This is increased very slowly at first, and at all times more slowly than the burden until the latter has reached about the figure for normal operation at the end of one or two weeks. Then the blast continues to be increased until it in turn has reached its normal amount and the furnace may be said to be in full operation.

Lighting the Furnace

The practice in this respect has varied over the widest possible range. My father, the late Joseph E. Johnson, told me that the practice of the old Southern charcoal "founders," who were entirely illiterate, was to light the furnace at the top and allow the fire to work down through the fuel column to the bottom, filling up above as the charcoal burned away, a process which took a week or two even with those tiny furnaces. Anything more absurd than this performance it is impossible to conceive.

As a result of this and some other practices based on reasoning about as fallacious, the furnace when blown in on one occasion got into such a horrible "mess" that at the end of three weeks it was blown out as being hopeless. They filled it and started again, and in a short time it was in worse condition than it was on the first occasion, but this time for shame's sake he insisted that the founder keep on, and they finally pulled the furnace through, rather in spite of that individual than with any help which the latter gave them.

These events took place in the early seventies, now more than forty years ago, but considering the changes which have taken place in this as in other departments of this business the time required for the transformation does not appear very great.

After the practice of lighting the furnace at the bottom was established up until very recently it was the custom to put a large quantity of wood into the hearth. This practice is still followed at some plants; in one case it is varied by using a carload of charcoal for the bottom of the furnace, this, of course, being very expensive in most localities.

When wood is used it is put into the hearth with the greatest care. In some cases in former times, and perhaps still at some plants, a scaffold or platform inside the hearth was built of wood and the cord wood was carefully placed on top of this, so that when the fire had burned the scaffolding sufficiently to break, the stock was given a sudden drop which started it to settling, it being a tradition, based, I think, on the rather defective practice of an earlier day, that it is very difficult to start a furnace to settling when it is blown in. When the scaffold was not used the wood was stood up vertically in the hearth and built up at least two lengths of cord wood 8 or perhaps 12 ft. or more, a small shaft being left to the last through which the wood, passed in through the tuyeres or tapping hole, could be taken up to the upper ranks, and through which the man who placed the wood could get down when that operation was finished.

In more recent years the tendency has been to discard the use of wood almost altogether. A few sticks placed around the tuyeres with a little kindling between them and the tuyeres are a convenience in getting the furnace lighted quickly. A few pounds of waste soaked in oil, pushed in through the tuyeres and ignited just before the blast is put on will ignite the coke with the use of no wood at all or at least only as much as may be put through the tuyeres. This saves a great deal of bother and in most cases saves a very considerable expense of cord wood, which costs several times more per unit of heat contained than coke.

One feature of practice in blowing in due to the dread of having the furnace hang at this time now fortunately belongs to a bygone era. It was then believed that the great height through which the stock had to fall in the early stages of filling the furnace tended to pack it solid and prevent the gas from rising, on the one hand, and the stock from settling, on the other. In order to avoid this difficulty, I am told that the practice was one time followed of lowering the stock into the furnace in tubs at the end of ropes, the tubs being dumped only when they were within a short distance of the stock already charged. I am extremely glad to say that I never had the misfortune to experience this operation, which is entirely obsolete as far as I know.

The universal custom now is to charge the furnace from the stack (after the wood had been placed, if any be used), exactly as is done in regular operation.

In former times it was customary to allow the furnace to draw, that is, leave the tuyere caps down and let the furnace act like a chimney, its draft, of course, being very greatly impeded by its being filled up with stock, over a period of hours ranging from two or three up to twenty-four.

I have seen this practice followed a number of times, and I have also seen and used the more recent practice of putting the blast on as soon as the furnace is lit, and I have never been able to see any advantages whatever in the old practice, whereas there are several in the latter. One of these is that the slow fire drawing gradually up through the furnace has the chance to bring some material to a half-molten condition and cause it to stick, while a quick blow-in does not. Another is the elimination of a half day or even a day of lost time and "sneaking" gas. I have never used the scaffold to cause the settling of the stock, but in recent years I have fol-

lowed a practice whose benefits I found almost by accident, and that is to give the furnace, for a few minutes after the fires at the tuyeres are well caught, about twice as much blast as it is expected to use for the rest of the blow-in. This drives the fire well to the center of the furnace to start off, and producing a brisk action before any pastiness has had a chance to arise from slow combustion induces a quick initial settling of the charge, which thereafter proceeds regularly on the reduced blast used for the rest of the blowing-in period. This practice also has an advantage in bringing down the gas, as it is called.

Bringing Down the Gas

When the furnace is first lit the interstices in the stock, the space above the stock line, the downcomer, and the dust catcher, and the flues leading to the burners on the stoves, boilers, etc., are, of course, all filled with air. Air mixed with furnace gas in a very wide range of proportions is highly explosive, and it was until very recent years considered a difficult feat to bring down the gas without having an explosion of more or less violence, because when the gas began to come through, driving the air ahead of it, the point would finally be reached where the mixture was a combustible one, and the flame striking back from the burners would ignite this mixture, and traveling back from the flue at least throw open all the explosion doors, and at worst burst the dust catcher or blow down part of the boiler settings.

In recent years there have been found two methods for avoiding this trouble which can be practiced separately or, still better, together. The first consists of providing at the extreme end of the gas flue, or on each end if it has several branches, an outlet with an explosion door, or other arrangement capable of being easily closed with the gas passing through it; the burners are all shut off tight, and the bell and other openings into the furnace and gas main system tightly closed, all the gas is then forced to pass off at these flue-end openings, from which all fire is carefully kept away. When a solid column of gas appears, which can easily be told, both by its appearance and its odor, the burners on the stoves and boilers are opened one at a time, and the dangerous mixture having all been pushed out of the flues far from these no explosion can possibly occur. The flue-end vents are then closed and all danger of explosion is over as long as the blast is kept continuously on the furnace.

The other expedient is one first used in the Birmingham district about the first of the present century. It consists in introducing a blanket or cushion of steam into the top of the furnace, dust catcher and flues before or at the time of lighting. This drives out all the air except the small amount in the interstices of the stock, and thereby prevents direct contact of the gas when it begins to rise with a sufficient quantity of air to produce an explosive mixture. When a sufficient volume of gas has passed to drive this cushion of steam out nothing but practically pure gas is left, and this may be ignited at the burners in safety. It is better, however, and safer to use this method in conjunction with the other by permitting the steam cushion to be blown out at the end vents of the gas flues, and thus securing the benefits of both methods. The steam-cushion method has in recent years been quite widely introduced by Mr. John W. Dougherty.

The benefit of a few minutes of extra blast in connection with bringing down the gas is that instead of having a very small quantity of gas formed, which appears to be almost lost in the interstices of the stock for quite a while, and which, therefore, prolongs the

period within which air mixture may be made and explosions follow, a considerable volume of gas is formed at once, and sweeping through the furnace drives out the air and shortens the period during which accidents may occur, as well as starting the stock to settling without delay.

Warming Up the Furnace Bottom

The bottom of the furnace contains many tons of brickwork which under the very best conditions can only have been warmed to a very slight degree by the drying-out fires previously described, and its temperature is many hundred degrees below the melting point of iron and slag. It therefore has the inevitable effect of chilling these and making the first tapping and flushing of the furnace extremely difficult. It has for a long time been the custom to leave the tapping hole open so as to allow the part of the gas formed at the tuyeres to blow down and pass out through this, thus making a downward current and warming the sole of the furnace. The tapping hole, however, as built in the brickwork is generally 2 or 3 ft. high, and if left entirely open the tendency of the gas would be to pass out through the top and not go to the bottom as it should. Moreover, it is necessary to have the tapping hole under control so that it can be closed at the first appearance of cinder, as not enough of this flows at first to keep on running, and cooling gradually it would build up until the hole could neither be opened nor shut without horrible difficulties.

This situation is met in recent years by placing a 4-in. pipe in the bottom of the tapping hole, running it well towards the center of the furnace, and filling up the space around this pipe with clay, sometimes mixed with fine coke braze so that it will not burn too hard. In the best practice this is built out to a convex surface well inside the line of the hearth proper, so that when the time to tap the furnace arrives the final point at which the body of iron is penetrated will be warmed as nearly as possible on all sides and so be made easy to penetrate.

Mr. R. H. Sweetzer has introduced an improvement in the use of the pipe by drilling holes in its outer ends through which it may be caught by means of long hooks and pulled out of the furnace when the slag begins to run, thus leaving a clean hole 4 or 5 in. in diameter in the clay which may readily be stopped with clay balls. The pipe is not removed for many hours after the blast is put on the furnace, not in fact until the flow of cinder becomes so large that it threatens to plug up the pipe by progressive flowing and freezing. The gas burns fiercely out the end of this pipe and helps to warm the iron trough outside, a point of very great importance, in order to prevent explosions when the molten iron strikes a cold iron surface.

The whole operation of blowing is one of some complexity, and it is virtually impossible to treat it completely here, there being many details which are neither comprehensible nor interesting, except to practicing furnace men, who commonly do not need to obtain them from books.

There are, however, a number of points in connection with blowing in which are worthy of mention. The practice of charging cinder saved from a previous blast on the blowing-in charge has been quite extensively followed and has much to commend it. High-temperature operations during the initial stages of blowing in are at a very serious disadvantage as the furnace temperatures are still too low for their accomplishment. We have already seen that the temperature required to form slag is considerably higher than its melting point, therefore a slag which has been completely formed melts much more easily and runs more freely at the tempera-

tures available during blowing in than the substance to be slagged, notably the coke ash, even though the latter have limestone charged with it.

Another reason for the use of slag is that a large volume of molten liquid is much less likely to become frozen and troublesome than a larger volume of the same liquid, the surface exposed by the larger volume in general being but little greater than that exposed by the smaller, therefore to increase artificially, so to speak, the volume of slag is a benefit and tends to prevent that troublesome occurrence of progressive building up through alternate blowing and freezing of which I have spoken. The practice of adding old slag is not as common as it once was, but its use is well worthy of consideration.

Slagging the Coke Ash

The great quantity of coke used as the initial portion of the blowing-in charge containing about 10 per cent of ash has in the aggregate several tons of slag-forming material, very largely silica and alumina with but little lime for flux. This makes alone a tough, stringy, hard working slag. It is very much better on every account to add to the coke as it is charged a sufficient amount of lime to flux this ash to the best advantage. As the first slag should be out of the furnace before any iron comes down it is not necessary that this first slag should have much sulphur-carrying capacity. It can be made much more fusible than the normal coke furnace slag by the use of a considerably smaller percentage of lime, thereby reducing both its quantity and melting temperature, but the slag produced just previous to the carrying down of the first iron should be slag almost of normal lime content, perhaps somewhat lower than this both for safety and because if the furnace is as hot as it should be, less lime is sufficient for desulphurization.

Pre-Heating the Stoves

The blast furnace process as a whole constitutes in a sense a cyclic operation. The blowing engines and the stove supply the blast which drives the furnace and the furnace in its turn supplies the gas which runs the blowing engines and heats the blast. But at blowing in a single furnace these conditions do not prevail. There is no gas available until after the furnace has been started. It is therefore necessary to fire the boilers with coal to make steam in the way customary where blast furnace gas is not available.

The stoves present a more difficult problem. We have already seen that under the very best circumstances the material which starts at the tuyeres when the furnace is blown in is nearly 3000 deg. below the temperature which it should have at that point. The blast is normally 1000 deg. or more when entering the tuyeres. If now with blowing-in we add to the effect of the cold stock inside the furnace the effect of blast 1000 deg. cooler than that which we should use it is obvious that we shall be a long time building up the temperature we require, and those who had the experience of it know that even 400 or 500 deg. of heat in the blast at this time is a great help as compared with cold blast. The stoves being entirely unprovided with grates cannot be fired to advantage with anything but gas, although a bonfire may be kept in the bottom of the combustion chamber by wood pushed through the burner or clean out openings, and this at least should always be done for several days continuously before blowing in.

Very much better than this, however, is the plan of building a temporary oven outside one of the air or clean-out openings best suited for it, arching it over or covering the top and connecting its outlet into the stove opening. Grate bars are then placed in the oven

and a good coal fire kept in it. The hot gases from this fire pass directly into the stove and if the operation be carried out with a little care and for several days before blowing in the stove can be in condition to give a temperature of several hundred degrees when it is finally wanted on the furnace. Of course care must be taken to see that the hot gases from the fire do not strike on the steel fittings around the stove openings or any metal part of the stove.

The question of drying out the furnace has already been discussed under the subject of lining and need not receive further consideration here.

Banking the Furnace

In the article on "Thermal Principles" the losses by radiation and cooling water were given in terms of thermal units per ton of iron, and while this is necessary and right for the purpose then in view, it must be remembered that heat losses are proportional to temperature and to time, and under given conditions to nothing else. Hence if we maintained the temperature of all the zones of the furnace exactly as it is in operation, but stopped the operation, made no iron, we should lose precisely as many thermal units in twenty-four hours as we do when the furnace is in full operation. We can put this into a more easily comprehensible form. If the total heat losses be 750 thermal units per ton, and if the furnace produces a ton of iron every three minutes, or 480 tons per day, we shall have a loss of 250 thermal units per minute, or in ten hours 336,000,000 thermal units. This is as much as is required for the smelting of twenty-five tons of iron, or in twenty-four hours we should lose as much heat as was required for the smelting of sixty tons of iron.

This loss is constant if the temperature of the furnace in all its zones be maintained constant, whether we make 500 tons per day or none, but if we make 500 tons' per day the loss only represents 10 per cent of the heat developed, and this the furnace can stand, but when no heat is being developed the furnace cools off very rapidly and of course the most rapidly in the zone of highest temperature, that is, the hearth. This means that the iron around the edges of the hearth soon begin to freeze and instead of having merely a thin scull of frozen iron to break through in tapping the furnace we shall have a scull of red-hot iron many inches in thickness, too hard to drive through, and much too tough and hot to drill except by the most tedious work. The consequence is that if a furnace shuts down for even a few hours in the regular course of normal operation much difficulty is experienced in opening the tapping hole, and the cinder notch, and in removing the frozen iron around the tuyeres which is often low in carbon and therefore tough, almost like wrought iron. Under these conditions operation can only be resumed with difficulty approximately proportional to the length of the stop. If there be iron in the hearth when the furnace is shut down this quickly freezes solid, filling the hearth with solid material, thus making it almost impossible to put the furnace back into normal operation. Because of course the regular tapping hole is frozen solid and cannot be used, the frozen iron in the hearth cannot be removed and the new iron formed when the furnace starts is raised far above its proper level and is continually threatening the cinder notch and tuyeres, while the mass in the hearth being heated only from the top melts very slowly. The furnace must be cast through the cinder notch or even through a tuyere, and in general the conditions of operation are terrific, nothing being arranged for those conditions.

For this reason if the furnace must be stopped for more than a very few hours provision is always made

for it in two ways. First of all by casting and removing as far as possible all the iron and cinder so there will be nothing left in the hearth to freeze. In good practice precautions are often taken in the stopping of the tapping hole; sand or braze is mixed with the clay for stopping the tapping hole so that it will not burn too hard. Second: if the stop is to be more than a few hours duration and if it be known beforehand that it is to be made, a blank of coke is charged at such a time that it will have descended about to the tuyeres by the time the stop is to be made. This gives an excess of fuel supply which becomes available as soon as the furnace starts up, and this excess heat is of the greatest use in restoring normal operating conditions.

Another beneficial feature is that the ore and limestone being absent from this coke charge there is correspondingly less molten material to descend into the hearth and freeze there while the furnace is stopped.

The size of the blank depends upon the length of the stop to be made. For a stop of a few hours duration only a single blank charge of coke may be used. But for a stop for two or three days a blank many times this size is required, and if the furnace is to be shut down for many days or perhaps several weeks, or indefinitely, as sometimes happens, then the furnace is practically filled altogether with coke.

After the furnace is stopped the greatest pains must be taken to shut off the tuyeres absolutely tight so as to prevent air from entering through them by natural draft. For very short stops this may be done by ramming clay balls through the blow pipes into the tuyeres and packing them there, while for longer stops the blow pipes are taken down and the tuyeres removed and a tight stop of clay put into the cooler. Of course the cinder notch and tapping hole are kept closed and if there are any cracks which have been blowing gas these should be luted up with clay.

It is surprising the amount of air which will draw into a furnace and the rate at which combustion will go on without blast unless special pains be taken to prevent it. This is objectionable because it burns up coke to no purpose and produces a corresponding quantity of slag in the hearth with the possibility, not to say certainty, that it will freeze there and make trouble on starting up. On long shut downs the cooling water on the furnace should be cut down to the merest trickle so as to prevent the removal of any more heat by this means than is absolutely necessary.

By following these precautions furnaces have been banked for months and then successfully started up again, but even with the best of management the long period of inaction is likely to bring about the sticking of material on the walls, and the consequent formation of scaffolds, such material would be scoured off as fast as formed during operation and scaffolds would therefore not occur. Moreover, even with the best of management the hearth builds up and its capacity is diminished, and in general that careful adjustment of all the conditions which the furnaceman may have been months in bringing about is upset, so that it is very rare for a furnace to work as well after a shut down as it has before for a considerable interval of time, this interval being in a general way proportional to the length of the shut down. That is to say, a furnace will quickly recover from the derangement of a six-hour shut down, but it will take in general nearly a day to restore equilibrium after a day's shut down, and a week or more when the furnace has been banked for several weeks.

The practice of banking furnaces is undoubtedly necessary at times, sometimes for physical and sometimes for financial causes, but for all these reasons it is a practice which breeds trouble, very often of long dura-

tion, and I believe that most furnacemen, if they knew in advance that a furnace had to be banked for a period of more than four weeks, would prefer to blow it out and blow it in again after the desired interval, and in my judgment this would be by far the wiser policy.

Blowing Out

We have seen that if the furnace be not kept full the gas passes off as the level of the stock descends past any zone in the furnace at the temperature which the gas has at that zone in normal operation. In other words, the temperature at that zone is approximately fixed as long as the surface of the stock does not descend below it; if there be stock above it, the gas will give up an amount of its heat roughly proportional to the heat of the stock above it, but if there be none, then the gas necessarily passes off at that temperature.

In blowing out, therefore, we lose the heat in the gas which we shall so badly need during the subsequent operation of blowing in to bring the materials of the charge up to their approximate temperatures at the different zones, but having no means to store this heat we have no recourse but to lose it. But it is worse than this; we not only lose the heat, but the temperature of the gas passing off rises from a temperature which iron and steel can ordinarily stand without any difficulty whatever, since the bell and hopper have habitually stood it for months and years together, to a temperature which is above the melting temperature of steel itself, and in consequence the gas destroys anything exposed to its action and not properly cooled.

In the days of furnaces with the center outlet and unlined downcomer, the latter could not be exposed to these gas temperatures without complete destruction and, protection to it being impossible, the entire top rigging of the furnace was taken off, bell, hopper, center outlet pipe, and practically everything of iron above the top of the furnace, this of course being done during a shut down of a number of hours for this purpose. After this operation was completed the blast was put back on the furnace and the gases allowed to pass out the top at will. They of course instantly burned on meeting the air at the top and a vast flame rising 100 ft. or more in the air was the result, this continuing until the furnace was blown out, that is, practically all the charge burned up.

In more recent years downcomers being lined throughout with brick, this condition does not exist, for while the bell and hopper are exposed to the gases they can be protected by filling the annular space between them with water and allowing enough to run into it continuously to supply that which boils away, and in consequence the operation of blowing out the furnace is much simplified. It is, however, very desirable to keep down the temperature of the gases as much as possible, and for this purpose water pipes are commonly introduced through the holes provided for the test rod and water is pumped into the furnace through these pipes, so cutting down the gas temperature very materially. I have found, however, that too heavy a column of water descending on the stock would make its way through the coke in spite of the ascent of the gas and so would chill the charge during blowing out. In order to obviate this I preferred to plug the end of the pipe and drill it full of holes for a distance of several feet so as to make a heavy spray of water. This cools the gas much more effectively and prevents the possibility of any solid body of water penetrating the coke.

When provision for cooling the gases in this way is made, and the charging space above the bell filled with water, virtually nothing more is needed but to put on the blast and keep on blowing until all the fuel in the

furnace is burned up. It is, however, desirable to have a fairly hot blowout so that the last iron and cinder to be removed may surely be hot enough to be tapped out of the furnace without any difficulty, and for this reason the burden is usually lightened somewhat.

The height to which it is desired to blow down varies according to the opinions of different furnace men. Some prefer to charge a large quantity of coke braize or poor coke which acts as a sort of piston and enables a little blast pressure to be kept upon the furnace until the charge proper is all burned out, this blow-out charge being then shoveled out after the furnace has been cooled down. The iron which lies down below the level of the outer end of the tapping hole cannot be lifted out by the blast pressure on blowing out because there is practically no stock in the furnace to make any blast pressure, and it is very undesirable to have this iron left in the furnace because it represents a decided loss of product and increases by so much the salamander which the furnaceman knows he will shortly have the pleasure of breaking up in the face of very considerable difficulties even under the very best conditions.

At one plant it is the custom to overcome this difficulty by removing the iron trough previous to the last cast, digging away the brick work on which it rests, making up a temporary sand runner to some pig beds at a correspondingly lower level and then drilling in at this lower level a foot or two below the level of the regular tapping hole and running in as nearly horizontal as possible. This drains the furnace down to a correspondingly lower level and removes most of the iron which would otherwise be left in a puddle in the hearth to freeze.

Relining

When the furnace is blown out it is generally necessary to make all repairs needed in the minimum time so as to get the furnace into operation again and cut off the loss which arises from the continuation of fixed charges whether the furnace is in operation or not, so that such repairs are generally made under pressure. These in general are various kinds of purely mechanical operation and need not be specially described here.

The operation of relining the furnace, generally the principal single item, is ordinarily the same as that of lining, since in most modern practice the old lining is torn out completely. There are, however, many cases in which the major portion of the lining is good and it is necessary only to put in a patch to repair a portion of it. It is obviously not possible to give detailed descriptions of this operation, which depends, as do so many other practical details of this business, on the skill and good judgment of the manager.

Removal of the Salamander

There is, however, one operation which is in a class by itself on account of the number of factors involved, and the weight of the pieces to be handled. This consists in the removal of the salamander. The formation and general nature of this has already been described. Its size varies considerably. In a charcoal furnace I have seen the hearth almost perfectly clean and smooth, the iron not having penetrated into the brickwork at all, but in coke furnaces with their higher hearth temperature and slags chemically much more active, conditions are very different. The bottom of the salamander is seldom less than 3 or 4 ft. and may be as much as 8 or 10 ft. below the original hearth level. Its diameter in general bears some relation to the original diameter of the hearth, usually larger than the diameter inside the brickwork and smaller than the diameter outside. This means a mass of metal anywhere from 8 to

20 ft. in diameter. I myself have had experience with salamanders weighing between 250 and 300 tons, this including only the single piece of solid metal in the central mass and not including the smaller but separate pieces lying around it and of course not including any brickwork, nothing but solid iron. I have no doubt that much larger salamanders than this are found in the largest size furnaces of the present day with their extremely large hearths.

If the hearth jacket is a permanent structure, which is generally the case under modern conditions, it necessitates removing this large mass of metal without disturbing the hearth jacket and, above all, without breaking the latter during blasting.

This of course increases the necessity for more care in handling the explosives required for this operation and incidentally increases the difficulty of hoisting the pieces out of the deep pit so formed.

Several years ago I described the operation of removing a salamander of about 130 tons weight from a small furnace, in an article which was published in the *American Machinist*, and as this gives a fair idea of the operation even for a larger furnace, portions of it are reproduced here.

Since the time this was written several cases have come to my notice of accidents due to the failure to explode one or more of the holes charged with dynamite. In one case this took place and afterwards a hole fired, presumably by the heat of the salamander, just as the furnace superintendent crawled in through the tapping hole to see what the effect of the shot had been. By great good fortune he escaped without permanent injury, though both his eyes and hearing were in danger for a long time, and a change of only a minute or two in the time of the accident might have resulted in his being blown to atoms. It is therefore worth a great deal of pains to see that holes do not fail to fire. The wires running to the exploders should be swung up out of contact with the salamander to prevent grounding, and instead of the common battery used for blasting a powerful electric light current should be thrown into the circuit to secure a sufficient volume of current to fire all the holes irrespective of the conditions. Of course vast masses of metal like this hold their heat a long time and the greatest precautions are necessary to prevent the dynamite being discharged from the heat soaking into it from the salamander. The holes as fast as drilled should have water put in them and it is better if this can be kept running constantly so as to cool the metal around the hole for a considerable distance. After each shot the heating effect of the blast is great and pains must be taken to see that this heat is removed before the hole is recharged.

The correctness of the general principle described above has been established by experience subsequent to that operation, using comparatively small charges at the bottom of holes of only moderate depth, by far the great portion of the hole being filled with tamping, and firing all the holes at once. The great tendency of professional blasters is, as they say, to "make sure you put in enough powder and then add a few more sticks for luck." This is the worst possible practice in blasting salamanders, for the reason that the expensive and time-consuming portion of the job is the drilling of the holes, and if these be loaded anywhere near full the top of the hole is blown out into a crater and the hole is destroyed. Moreover, the pieces of iron thrown out of the crater do many times more damage than all the other blasting put together, since they act as projectiles with an enormous charge behind them, whereas the splitting of the salamander itself produces no shock except that of the blast on the air.

The Present Status of the American By-Product Coke-Oven Industry

In our issue of May 1 we gave on pages 502 to 504 a report of a very interesting paper, read on the American by-product coke-oven industry by Mr. T. C. Clarke, consulting engineer of New York City, before the New York Section of the Society of Chemical Industry.

Limitations of space in our last issue forced us to withhold several portions of Mr. Clarke's paper. These are herewith reported.

PROGRESS IN DESIGN AND COSTS

Among the interesting details in changes of design made in the course of years, Mr. Clarke mentioned the following:

At first the gas nozzles used to carbon up, impeding the flow of the gas and in consequence making "cold spots." To correct this the nozzles were changed at frequent intervals when they showed signs of carboning, but now the gas is cut off a moment or two before reversing, while the air is left on, and so the carbon is burned out. The pipes connected with a fire brick flue for the supply of gas, have plugs at all their angles, so that the plugs may be taken out and pipes cleaned. Peep holes are put in across the top of the oven at every flue and through these the man in attendance can observe and regulate the condition of the gases burning in the flue.

In years gone by the amount of surplus gas available was guaranteed by the oven builders to be 5000 cu. ft. of gas per ton of coal coked of a B.t.u. value of 500 per cubic foot. When in Chicago the other day Mr. Clarke visited a plant that has been in constant operation twenty-seven months, where the yield of surplus gas was 6250 cu. ft., and the B.t.u. value 590. He is creditably informed there is one plant where the surplus gas runs to 6600 cu. ft. This marked improvement, of course, is only possible where the air is absolutely excluded, as leaks would prevent any such results. This condition reflects the highest credit on the oven designers who have made such allowances for the expansion of the materials employed in construction that they can get such results.

The oven size has gone from a capacity of $4\frac{1}{2}$ tons to $13\frac{1}{2}$ tons of coal. At the present time this seems to be about the standard, although some of the engineers are now advocating $12\frac{1}{2}$ -ton ovens. While it varies with different coals, an oven is generally about 17 in. to 22 in. wide, with a taper; this being necessary to facilitate pushing the coke. The height of the oven is about 10 ft. and the length from 35 to 40 ft.

The doors which used to be a flat metal frame with a fire brick insert, causing what were known as "black ends" as the coal in the oven projected beyond the flues, are now made deep like a plug which goes into the oven far enough to hold the coal at the level of the first flue.

The cost of the oven has increased from about \$7,500 per oven to nearly \$20,000 per oven. This, while seemingly excessive is easily explained by the increased weight of all the material entering into the construction of the ovens and their accessories and the fact that for this amount of money the maintenance and conversion cost has been cut to well below 60 cents per ton of coal coked. Taking as an example coal around $28\frac{1}{2}$ per cent volatile, with the ordinary yields a typical balance sheet for a 100-oven plant of $13\frac{1}{2}$ tons per oven capacity on an 18-hour coking time would be as shown in Table I. making the cost of coke \$6,629.52 — \$3,064.01 = \$3,555.51. With a 70-per cent yield 1236 net tons of coke are obtained from 1766 tons of coal, so that the coke costs \$2.88 per ton. That is, the ton of coke is

TABLE I

Daily Expenditure	
1766 tons of coal, at \$3 per ton.....	\$5,298.00
Conversion cost, including depreciation, contingencies and charges of every character.....	1,059.60
Except interest and administration, 60 cts. per ton.....	
Interest on investment of \$2,000,000 at 5 per cent, \$100,000.....	
22 cents per ton of coke, 1236×22	\$271.92
	\$6,629.52
Receipts	
Tar, 7 gal. per ton of coal, at $2\frac{1}{2}$ cts. per gal.....	\$309.05
Sulphate, 1 per cent, at \$60 a ton.....	1,059.60
Gas, 6000 cu. ft., at 10 cts. per cubic foot.....	1,059.60
Benzol, $2\frac{1}{4}$ gal., at 14 cts., i. e., 20 cts. less 6 cts. conversion.....	556.29
Toluol, 0.3 of a gal. at 15 cts. per gallon.....	79.47
	\$3,064.01

obtained for less than the ton of coal costs, and we have 10,500,000 cu. ft. of available surplus gas on 550 B.t.u. value at 10 cents per 1000 cu. ft. and a uniform coke both physically and chemically, and depreciation and interest taken care of.

At present war prices the fortunate owners of by-product coke ovens selling their benzol at \$0.50 per gallon and their toluol at \$4.50 a gallon, find their coke costs them nothing and then they earn about \$450 per day besides. Free blast-furnace fuel makes for low costs and increased earnings.

When changing from 24-hour coking time the tendency was to reduce the time as low as possible, (and coke was successfully made under 16 hours), but the high heats employed made this practice most dangerous, for neglect at any time would melt the oven, so gradually the heats were brought back until a time was reached which the consensus of opinion deemed to be economically balanced. This time was 18 hours, and the ovens after running for long periods on these heats show no signs of deterioration.

RECOVERY OF TAR AND AMMONIA

In discussing the subject of tar and ammonia recovery, Mr. Clarke pointed out that this has shown the least improvement. In Germany and England the tar recovery is much better than with us. Theoretically our coals should yield more than 7 gal. and ammonia more than 1 per cent.

As the coking time was brought down, the yields of tar and ammonia went with it, and frankly as the coke ovens are principally being run to supply metallurgical coke, this subject has not been given the attention that it deserves. The benzol industry is, with the exception of the Semet-Solvay Company, in its infancy. Plants are being built in practically every coke-oven installation since the war began, and what the result will be after the war, remains to be seen. Logically its first and greatest market will be as motor fuel. The production now of gasoline from crude oil is

Gasoline Produced		Crude Oil Produced	
	Barrels		Barrels
1904.....	5,320,000	1904.....	117,100,000
1909.....	12,900,000	1909.....	188,200,000
1914.....	34,915,000	1914.....	265,800,000
1915.....	41,600,000	1915.....	267,400,000
Licenses, Automobile			
1905.....			\$5,000
1910.....			400,000
1914.....			1,253,000
1915.....			1,750,000
1916.....			2,225,000

It is interesting to note that while the production of crude oil from 1914 to 1915 advanced only 2,000,000 barrels, gasoline in the same period advanced nearly 7,000,000 barrels.

Assuming the production of the old type ovens at 5 tons of coal per day of twenty-four hours, and the larger ovens at 15 tons, and getting a yield of two and a half gallons of 50 per cent benzol per ton, we find the benzol

production to be 85,990,000 gallons or 2,694,000 barrels per annum. Fear has been expressed that after the war the sudden dumping on our markets of 85,000,000 gallons of motor fuel would break the price badly and make a number of lean years for the coke oven benzol producers.

"Without desiring to join the ranks of Ford advertisers, I should like to call one thing to your attention. If 200,000 of the 300,000 Ford cars produced annually remain in this country and have an average mileage of 5000 miles per car and consume a gallon of gasoline for every fifteen miles, the annual consumption will be 66,666,000 gallons. Since the benzol output if all sold for motor spirits only amounts to 84,990,000 and one make of car uses 66,000,000 with the increase in automobile production that the statistics above show, it seems to me we are fortunate that we have a new fuel coming on the market."

The production of tar in gallons in 1905 was 36,379,000, in 1910 it was 69,780,000 gallons, and when the various plants now built and building are in operation, these figures will advance to 237,947,000 gallons of tar. Sulphate of ammonia productions in 1905 in the United States was 65,000 tons of 2000 lb., in 1910 it was 115,000 tons. When the present ovens now built and building are operating, the production will be about 340,000 tons. The price of these commodities has been 2½ cents per gallon for the tar and for the sulphate of ammonia around \$60 a ton for the past ten years.

Mr. Clarke then gave what appears to be the most up-to-date list of by-product coke ovens built or in course of construction in the United States. (Table II.)

COMPARISON OF AMERICAN AND EUROPEAN PRACTICE

Mr. Clarke then stated that two years ago he visited most of the by-product coke ovens in the Durham and Middlesborough district in England, and a great many of the ovens in the triangle formed by Düsseldorf, Dortmund and Wesel, which is the lower Rhine Westphalian steel district. After having seen just before he left the practice and mechanical refinements of the Gary plant, visiting the coke oven operations in Europe brought back very vividly to him the American practice of ten years ago, and "one realized how entirely we had gotten away from the old world's standard."

There were only two things that he saw where he considered Europe was in advance of us. One was a gas engine installation, and the other in the use of mixed gases. At one of the big German steel plants they have a 10,000-hp. installation of gas engines, generating electricity which cost them complete \$300,000. That same installation over here would have cost \$1,000,000, which may explain why the large gas engine unit is less in vogue here than there.

The other instance was at Skinninggrove, where Mr. Ernest Bury, who has contributed liberally to coke oven data, in a number of papers he has presented before various bodies in England, took the visitors through his plant, where he was using a mixture of three volumes of blast-furnace gas with one volume of coke-oven gas, and getting a mixture about as follows: hydrogen 13.25, methane 0.75, unsaturated hydrocarbons 0.5, carbon monoxide 22.75, carbon dioxide 9., nitrogen 47., B. T. U. per cubic foot 206. He was using this gas in his gas engine to produce electricity; also in the open-hearth furnaces and in the soaking pits. These gases replaced producer gas of analysis running in hydrogen from 9. to 14. methane 2. to 3.5, carbon monoxide 22.28, carbon dioxide 3. to 6., nitrogen 55. to 60., B.t.u. 125. to 175. "That we will come to use a mixture of this kind I am confident, especially as natural gas, which has been so instrumental in building up the steel industry in Pennsylvania, is rapidly beginning to show signs that it can-

TABLE II.—LIST OF BY-PRODUCT COKE OVENS OF THE UNITED STATES NOW BUILT AND IN COURSE OF CONSTRUCTION

	Type	No. Benzol
American Steel Wire Co., Cleveland, Ohio	Koppers	180 Yes
Allegheny By-Products Coke Co., Glassport, Pa.	Otto	120 Yes
Buffalo Union Pee. Co., Buffalo, N. Y.	Roberts	60 Yes
Brier Hill Steel Co., Youngstown, Ohio	Koppers	84 Yes
By-Product Coke Corp., South Chicago, Ill.	Semet S	280 Yes
Cambria Steel Co., Johnstown, Pa.	Koppers	372 Yes
Cambria Steel Co., Johnstown, Pa.	Koppers	92 Yes
Central Indiana Gas Co., Muncie, Ind.	Klome	22 ?
Citizens' Gas Co., Indianapolis, Ind.	Otto	100 Yes
Coal Products Co., Joliet, Ill.	Koppers	35 Yes
Coal Products Co., Joliet, Ill.	Willputte	18 Yes
Central Iron & Steel Co., Tuscaloosa, Ala.	Semet S	60 Yes
Cleveland Furnace Co., Cleveland, Ohio	Semet S	100 Yes
Chattanooga Gas Co., Chattanooga, Tenn.	Roberts	12 ?
Carnegie Steel Co., Union, Pa.	Koppers	640 Yes
Colorado Fuel & Iron Co., Pueblo, Col.	Koppers	120 Yes
Empire Coke Co., Severn, N. Y.	Semet S	35 Yes
Gulf State Steel Co., Gadsden, Ala.	Koppers	37 Yes
M. A. Hanna & Co., (Dover By-Product Coke Co.), Canal Dover, N. Y.	Roberts	24 Yes
Inland Steel Co., South Chicago, Ill.	Koppers	86 Yes
Inland Steel Co., South Chicago, Ill.	Koppers	44 Yes
Indiana Coke & Gas Co., Terre Haute, Ind.	Gas Machine	30 Yes
Indiana Steel Co., Gary, Ind.	Koppers	260 Yes
Illinois Steel Co., Joliet, Ill.	Koppers	280 Yes
Kentucky Solvay Co., Ashland, Ky.	Semet S	108 Yes
Lehigh Coke Co., Bethlehem, Pa.	Didler	40 Yes
Lehigh Coke Co., South Bethlehem, Pa.	Koppers	424 Yes
Laclede Gas Light Co., St. Louis, Mo.	Koppers	94 Yes
Lackawanna Steel Works, Pottsville, W. Va.	Otto	185 Yes
Lackawanna Steel Co., Buffalo, N. Y.	Rothberg	280 Yes
Lackawanna Iron & Steel Co., Buffalo, N. Y.	Otto	232 Yes
Maryland Steel Co., Sparrows Point, Md.	Koppers	120 Yes
Minnesota Steel Co., Duluth, Minn.	Koppers	90 Yes
Michigan Alkali Co., Wyandotte, Mich.	Semet S	30 Yes
Milwaukee Coke & Gas Co., Milwaukee, Wis.	Semet S	160 Yes
New England Gas & Coke Co., Everett, Mass.	Otto	400 ?
National Tube Works, Benwood, W. Va.	Semet S	120 Yes
Niagara Coke Corp., Buffalo, N. Y.	Otto	100 Yes
Northwestern Iron Co., Mayville, Wis.	Otto	72 Yes
North Shore Gas Co., Waukegan, Ill.	Semet S	13 No
Pennsylvania Steel Co., Lebanon, Pa.	Semet S	120 Yes
Pennsylvania Steel Co., Steelton, Pa.	Semet S	40 Yes
Philadelphia Suburban Gas & E. Co., Chester, Pa.	Semet	40 Yes
River Furnace Co., Cleveland, Ohio	Koppers	204 Yes
Republic Iron & Steel Co., Youngstown, Ohio	Koppers	143 Yes
Semet-Solvay Co., Dunbar, Pa.	Semet S	110 Yes
Solvay Process Co., Delray, Mich.	Semet S	175 Yes
Solvay Process Co., Syracuse, N. Y.	Semet S	40 Yes
Sharon Coke Co., Sharon, Pa.	Otto	212 Yes
South Jersey C. E. & T. Co., Camden, N. J.	Otto	150 Yes
South Jersey C. E. & T. Co., Camden, N. J.	Koppers	45 Yes
Seattle Lighting Co., Seattle, Wash.	Klome	22 Yes
Seaboard By-Product Coke Co., Jersey City, N. J.	Koppers	110 Yes
Tennessee Coal & Iron Co., Ensley, Ala.	Semet S	240 Yes
Toledo Furnace Co., Toledo, Ohio	Koppers	280 Yes
United States Furnace Co., Canton, Ohio	Koppers	94 Yes
Western States Coke Co., St. Paul, Minn.	Koppers	47 Yes
Woodward Iron & Steel Co., Woodward, Ala.	Koppers	55 Yes
Youngstown Sheet & Tube Co., Youngstown, Ohio	Koppers	170 Yes
Zenith Furnace Co., Duluth, Minn.	Koppers	204 Yes
	Otto	65 Yes

not be counted on in the future as it has been in the past."

The advantage of the use of these gases is that a constant supply of uniform composition and calorific value is always available. In the case of melting furnaces the cost per ton of ingot is less than that of producer gas, and there is no standby loss. No space is needed for fuel storage. There are no labor repair costs, and constant supervision, in order to procure producer efficiency is eliminated. In good blast-furnace practice, where the gases are efficiently washed they are using about 30 per cent of the total volume of the gas for stoves, 7.5 per cent for the boilers, and 12.5 per cent for blowing engines, and there is a 5 per cent loss in washing, etc., leaving a surplus of available gas of from 40 to 45 per cent. This gas has a value of between 90 and 100 B. T. U's. The volume of gas depends, of course, on the amount of air that is being blown and what the charge is, but will amount in the case of a modern furnace to around 25,000,000 to 30,000,000 cubic feet per day per furnace.

By mixing this low-B. T. U. value gas with the richer coke oven gas, making an average of 200 to 250 B. T. U.'s per cu. ft. mixture, an increased supply of calorifically uniform fuel gas is obtained, which undoubtedly is advantageous.

"With the exception of these two things, I can truthfully say that the European practice, excepting in ammonia and tar yields, is in no way comparable to the present United States practice, and in engineering and amount of production we are immeasurably superior to our instructors."

In the conclusion Mr. Clarke pointed out that the changes which are occurring from day to day in the American by-product industry are so numerous and may be so important that "one cannot help feeling that two years from now everything said tonight will be obsolete, excepting for the two principles involved, uniformity in the coke and regularity in the operation and in the temperature of the ovens."

Capacity and Economy of Multiple Evaporators

Professor E. W. Kerr, of Louisiana State University and A. & M. College of Baton Rouge, La., has contributed in the past to the profession a series of valuable papers on evaporators and vacuum pans, and their performance with special reference to sugar-house practice (see our Vol. XI, pages 333 and 611, 1913, and Vol. XIII, pages 485 and 551, 1915).

At the recent meeting of the American Society of Mechanical Engineers in New Orleans Professor Kerr presented another interesting paper on the "Capacity and Economy of Multiple Evaporators." An abstract of this paper is herewith given.

The process of evaporating in sugar-factory work consists of two distinct parts: First, the juice with a density of 12 deg. to 18 deg. Brix is concentrated by evaporating off part of its water to approximately 55 deg. Brix in a multiple evaporator; second, the syrup produced is then taken to a vacuum pan working single effect, and where further water is removed by evaporation under conditions suitable for crystallizing the sugar, the final density being in the neighborhood of 95 deg. Brix.

Professor Kerr's present paper deals with the first part of the process, namely, the evaporation in multiple effect. The capacity of multiple-effect evaporators depends on two general factors: the coefficient of heat transmission and the temperature fall from one effect to the next effect.

The coefficient of heat transmission depends on the following nine factors:

1. (a) Steam distribution, (b) steam velocity.
2. Density of heating steam.
3. Quality of heating steam (whether superheated or not).
4. Presence of air or other incondensable gases in the steam, which may be expressed mathematically by the ratio $P_s \div P_r$.
5. Presence of condensation on the heating surface.
6. Cleanliness of heating surface (steam side).
7. Material, thickness and molecular structure of tubes.
8. Cleanliness of heating surface (liquor side).
9. Velocity of liquor circulation.

The heat transmitted from steam through a metal wall to a liquid being boiled takes place in three steps: First, from the steam to the initial surface of the metal (this is affected by the above items 1 to 6); second, from the initial surface through the metal wall to the cooler surface (item 7); third, from the cooler surface to the liquid being boiled (items 8 and 9).

The temperature fall depends on the following six factors:

10. Pressure of steam supplied to first body.
11. Vacuum in last body.
12. Hydrostatic head (height of boiling).
13. Presence of air or other incondensable gases in the steam (see item 4 above).
14. Density of liquor being boiled.
15. Purity of liquor being boiled.

Factors Affecting Heat Transmission

DENSITY OF HEATING STEAM

Although in many respects evaporators are similar to surface condensers, there are certain fundamental differences. In surface condensers, the density of the heating steam varies between very small limits, corresponding to vacuums of, say, 24 to 29 in., whereas in evaporators the steam pressure varies from about 5 lb. per square inch gage in the first body to a vacuum of about 15 in. in the last body, with corresponding variations in density.

In surface condensers, air is the only incondensable gas, and it enters with the steam, also by leakage through joints and metal pores; in evaporators, other incondensable gases, such as ammonia, sulphur fumes, etc., entering with the juice, have to be contended with. Evaporator shells also furnish larger areas in contact with the atmosphere per unit of capacity than do surface condensers, thus increasing the danger of air leakage.

In surface condensers, the danger of scale or other fouling of tubes is confined mainly to the steam side, the high velocity of the cooling water preventing any fouling on the other, even with bad water; in evaporators, however, the larger part of the fouling is on the liquor side. The tendency to fouling depends on the condition of the juice as to density, materials used in clarification, etc.

In surface condensers the velocity of the cooling water is produced by a pump or other mechanical means, whereas in evaporators the circulation is produced by convection and steam currents.

In surface condensers the factors hydrostatic head, density of liquid and purity of liquid do not enter, whereas they are important in connection with evaporators.

QUALITY OF HEATING STEAM (WHETHER SUPERHEATED OR NOT)

The effect of superheat in steam on the coefficient of heat transmission is not very well known, the results of different experimenters being more or less contradictory. The author's experiments seem to show that superheat does not affect the coefficient of heat transmission, and results by other recent experimenters substantiate this.

Operators, on the other hand, frequently state that greater capacity can be obtained with exhaust steam than with live steam. Most evaporators are arranged to use live steam in case the exhaust steam supply is insufficient; boiler steam is throttled down to the necessary low pressure, resulting in superheating the steam, and the importance of the matter lies in this. Professor Kerr concludes that in all probability the apparent reduction in capacity noticed with the use of live steam is due to the live steam pipe being too small to supply steam to the evaporator at a pressure equal to that in the exhaust main.

PRESENCE OF AIR AND OTHER INCONDENSABLE GASES IN THE STEAM

The presence of air and other incondensable gases is doubtless one of the most fruitful causes of low heat

transmission. It is probable also that less is known about this factor than any other involved. Air-free steam is practically impossible, and, as stated, the conditions in this respect are less favorable in evaporators than in surface condensers.

As the result of a large number of experiments on surface condensers, George A. Orrok states that the heat transmission coefficient varies according to the expression $(P_s + P_r)^2$, in which P_s represents the partial steam pressure and P_r the total pressure of steam and air combined. Experiments by Professor Kerr on laboratory evaporators seem to show that the exponent in the above expression lies somewhere between 3 and 4.

A considerable amount of experimenting on this subject has been done recently by Professor Kerr. Temperatures were measured at different portions of a laboratory calandria on the basis that the greater the amount of air in any locality of the steam compartment, the lower the temperature there. Typical results are given in the paper. The thermometers were inserted through the shell at points indicated in the table, and were made to extend a few inches into the steam compartment. The figures show very clearly that there was considerable variation of temperature in different parts of the calandria, and also a shifting of temperatures. Some temperatures were found higher than the saturation temperature and some lower; the former were due to superheat and the latter to the presence of air.

These data seem to show that there are air pockets, changing from place to place; also that there is practically the same temperature at all points when the evaporator is boiling at a high rate, the velocity of steam being much greater in this case.

The prevention of these air pockets is a matter for the consideration of designers. It seems reasonable to expect that air pockets will form in dead spaces, *i.e.*, where there is little or no movement of steam, and for this reason good distribution is very important. High velocities produced by means of baffles, etc., should result in the prevention of air pockets.

In practice some of the air is removed by means of the condensation pumps which draw from the bottom of the steam compartment, and some is vented from the top through small openings connected either to the next body or direct to the condenser. This statement applies particularly to the more common types—vertical juice-tube evaporators and horizontal steam-tube evaporators. Other special types make use of various devices, in some cases each tube having its individual vent. In some types the vents can be controlled, while in others they cannot.

One of the great difficulties is the impossibility of removing the incondensable gases without removing steam along with them and reducing the economy.

In addition to its insulating effect, air in the steam reduces heat transmission by causing a temperature fall lower than the apparent fall. This is because the temperature of the heating steam is lower than the saturation temperature corresponding to the pressure.

CONDENSATION ON THE HEATING SURFACE

The loss in capacity due to the presence of condensation on the heating tubes depends upon the type and design of evaporator. The bottom portions of long vertical tubes will be affected more than those of shorter ones. In vertical juice-tube evaporators the water, after reaching the lower tube sheet, must zigzag among the tubes to reach the outlet. Tube sheets are inclined by some makers to facilitate the removal of condensation. Occasionally the tubes themselves are inclined so that the condensation runs along the underside of the

tube in attenuated form to the bottom, the idea being to reduce the amount of surface in contact with the water. The removal of water is also facilitated by using multiple outlets, reducing the distance the water has to travel along the bottom tube sheet. In horizontal steam-tube evaporators, the condensation gravitates to the lower side of the tube and is blown through by the steam.

CLEANLINESS OF HEATING SURFACE ON THE STEAM SIDE

The fouling of the heating surface on the steam side is mainly due to oil in the exhaust steam coming from the engines. An oil separator in the supply pipe to the evaporator aids in overcoming this difficulty, and when steam turbines are used as prime movers the difficulty is avoided.

In vertical juice-tube evaporators there is little opportunity for cleaning the oil scale from tubes, as the latter are difficult of access. A very efficient means of cleaning them is to fill the steam compartment with molasses during the off-season; the acid in the molasses attacks the scale and removes it.

Steam-tube evaporators have the advantage that mechanical cleaning by means of swabs is possible. This can be done with the tubes in place. Tubes in this type are usually removable, however, and this facilitates cleaning.

MATERIAL, THICKNESS AND STRUCTURE OF TUBES

Evaporator tubes are generally made of copper or brass, more often the former. The thickness is usually about 1/16 in., ranging from 14 to 18 B.W.G. Within this range of thickness the variation in the coefficient of heat transmission is practically negligible. In standard evaporators the most common size is 2 in. diameter by 48 in. long. Steam tubes are usually of smaller diameter and much longer, a common size being 3/4 in. diameter by 12 ft. to 14 ft. long.

CLEANLINESS OF HEATING SURFACE ON LIQUOR SIDE

The fouling of tubes on the liquor side presents a difficult problem. The rapidity with which scale forms depends upon several factors, such as method of clarification used, amount of lime used, quantity of gums remaining in the juice after clarification, velocity of juice circulation, etc. This scale collects on the inside of juice tubes and on the outside of steam tubes. It can be removed by filling the juice compartment with a solution of soda or hydrochloric acid and boiling; it is generally necessary to do this about once a week. The juice scale is usually worse in the last bodies on account of the increased density of the juice.

Makers of some special types of evaporators claim for them that the juice scale can be removed by reversing the flow of vapors. The cool body is thus made the hot body, and expansion of the metal of the tubes cracks the scale.

A very convenient way to clean the tubes of standard horizontal evaporators is to remove them and crack the scale by mechanical means.

VELOCITY OF LIQUOR CIRCULATION

Rapid juice circulation is also a factor in securing efficient heat transmission. The heat transmitted through the tube walls produces vapor bubbles which tend to collect on the surface of the tube, and in turn prevent heat transmission. A rapid circulation brushes these bubbles away and increases the number of contacts between the cooler surface and the liquid. As stated, circulation is produced in evaporators by convection and steam currents, except in a few special types. In vertical juice-tube evaporators the velocity varies with the

proportions of the tubes; that is, with the ratio of the heating surface per tube divided by the carrying area of the tube.

A matter of considerable importance is that of entraining or priming. Vertical juice tubes especially are likely to *spout* if they are forced too hard. This can be overcome, however, by the use of baffles in the vapor space and by means of separators in the vapor pipes. The circulation in horizontal evaporators is less rapid and not so well defined as in vertical evaporators having usually a central downtake or circulation tube.

Factors Affecting Temperature Fall

STEAM PRESSURE IN FIRST BODY AND VACUUM IN LAST BODY

Important among the factors affecting temperature fall are initial steam pressure and vacuum in last body. The former is limited, 5-lb. gage being an average, with 10 lb. the maximum. If sugar juice is boiled at a temperature above 220 to 230 deg. Fahr. there is danger of injuring the sugar. High pressure also reduces the capacity of the mill and other engines due to the high back pressure.

The vacuum in the last body is generally about 26 in. With 10 lb. initial steam pressure this would give a total temperature fall of 114 deg., and a pressure of 5 lb. would give a total fall of 102 deg., which must be divided among the several bodies of a multiple effect. This means greater temperature fall and capacity per unit of heating surface in a triple than in a quadruple, and still more in a double. Simple calculations will show that a decrease of pressure at the condenser end will increase the total temperature fall much more than will an equal increase of initial pressure.

Some have contended that high vacuum is desirable, and it is not uncommon to specify a vacuum of 27 in. for evaporator installations. It is doubtful, however, if a vacuum higher than 26 in. is desirable, especially in submerged tube evaporators which operate with considerable hydrostatic head.

HYDROSTATIC HEAD

Hydrostatic head (submergence of the heating surface) decreases heat transmission by increasing the temperature at which the liquor boils. This makes the temperature fall less than that ob-

tained by subtracting the temperature corresponding to the vapor pressure from the temperature of the steam in the calandria (apparent temperature fall). This loss varies in the different bodies inversely with the absolute pressure of boiling; that is, with a given height of boiling the loss will be greatest in the last body and proportionately less in preceding bodies. The original paper gives the loss due to hydrostatic head for the three bodies of a triple effect with apparent temperature falls of 20 deg., 30 deg., and 50 deg. respectively in the first, second, and third bodies, with heads varying from 0 to 48 in. Developments in evaporator design have been largely affected by this question. The loss due to hydrostatic head is greatest in vertical submerged tube evaporators, and is less in horizontal steam tube evaporators, while film evaporators avoid it entirely. In view of the large loss due to this cause when the absolute pressure is very low, film evaporators can make better use of high vacuum in the last body than can submerged tube evaporators.

DENSITY AND PURITY OF LIQUOR

High density of the liquor being boiled causes reduced heat transmission by making the actual temperature fall lower than the apparent fall.

This loss is still greater with sugar solutions of low purity. For example, in a sugar solution with a density of 70 deg. Brix and a purity of 100 per cent, the boiling temperature is about 12.5 deg. above the saturation temperature of steam, whereas with the same density and a purity of 60 per cent the temperature of boiling is approximately 18.5 deg. above the saturation temperature of steam.

Tests of Evaporators in Sugar Factories

The second part of Professor Kerr's paper gives the results of tests of evaporators of commercial size and under regular operating conditions in sugar factories.

Observations were made of practically all factors which might affect the results. A typical log included observations of the pressure or vacuum in the steam or vapor space of each body; temperature and density of the juice entering and leaving; weight of juice entering and leaving; weight of condensed steam from the first body, etc. Concerning details of the measurements and calculations employed, the reader must be referred to the complete paper. We give only the results.

The evaporators tested included double, triple, and quadruple effects of the following types:

(A) Vertical submerged tube (so-called standard, Fig. 1).

(B) Horizontal steam tube (Figs. 2a and 2b).

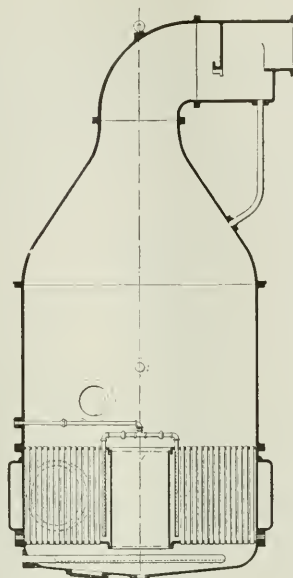


FIG. 1—ONE BODY OF VERTICAL SUBMERGED TUBE EVAPORATOR WITH BELT STEAM DISTRIBUTION (TYPE A)

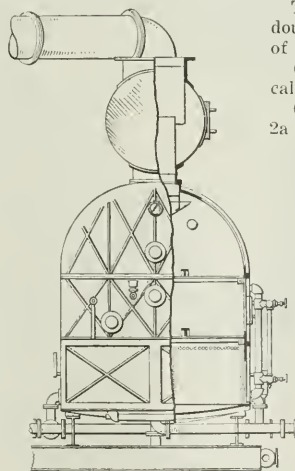


FIG. 2A—ELEVATION OF HORIZONTAL EVAPORATOR (TYPE B)

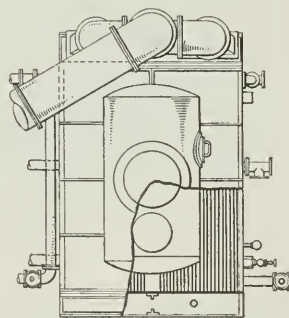


FIG. 2B—PLAN VIEW OF EVAPORATOR, FIG. 2A

(C) Horizontal film evaporator, as illustrated in Fig. 3 diagrammatically.

(D) Vertical film evaporator, as illustrated diagrammatically in Fig. 4.

(E) Standard type with special baffle steam distribution, running under vacuum (illustrated in Fig. 5, page 607).

(F) Same as E, but with atmospheric pressure in last body, no vacuum apparatus being used.

(G) Vertical steam tubes with special means for venting each tube (double tube, illustrated in Fig. 6, page 607).

Types A and B (Figs. 1 and 2) are so familiar that it is not necessary to describe them. The majority of the sugar house evaporators used in practice belong to one or the other of these two general types.

In type C, Fig. 3, the horizontal tubes are expanded at one end into a thick tube plate, and at the other are closed except for a small vent which releases the incondensable gases into the vapor space. The water of condensation leaves the tube at the end where the steam enters. Juice is supplied by centrifugal pumps to a distributor above the tubes and falls in a film from one tube to another. The piping is such that the juice may be recirculated over the tubes until the desired concentration in each body is obtained.

In the vertical film type D, Fig. 4, the juice level is near the bottom of the tubes, the latter being approximately 20 ft. long. A rapid current of steam rising through the tubes sweeps juice along with it. The pressure of the steam on the interior of the tube keeps this juice as a film (often referred to as *climbing film*) on the tube surface. The juice, thus projected upward, on issuing from the tops of the tubes enters a special separator which separates it from the vapor. The juice and vapor then pass from body to body in the usual manner.

In interpreting the results of tests of evaporators it is of utmost importance to take into consideration that the conditions of operation are often very different. Some important differences of practice may be stated as follows:

The removal of condensation from the steam compartments may be effected by:

- Pumps from each body.
- Siphoning the condensation from body to body, a pump being used to remove it from the last body.
- Barometric leg pipe; this method can be used only in case the evaporator is high enough to give a

column of water sufficient to balance the vacuum in the space being drained.

The venting of incondensable gases may be effected by:

(a) Small pipes tapped through the shell just under the top tube sheet.

(b) Small pipes tapped into the top tube sheet and located near the downtake. Usually two or four of these tubes are used, which are connected together inside of the vapor space with a single pipe brought through the shell and a valve placed on the outside for control.

(c) In horizontal evaporators, the steam chest opposite the steam entrance is vented.

(d) Special methods depending on the type of evaporator.

In all of the above the vented gases may be taken direct to the condenser or to the next body, though so far as heat transmission is concerned, it is doubtless better to vent direct to the condenser. Usually valves are placed in vent lines in order that control may be exercised. In some cases the venting is continuous and in other cases intermittent, depending upon the ideas of the operator. In types C and G special means of venting are used which have been explained above.

Finally, the condition of the heating surface (whether freshly cleaned or not) is naturally of greatest importance for the performance of an evaporator.

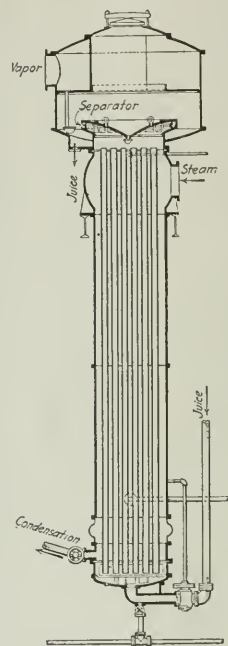


FIG. 4—ONE BODY OF TYPE D EVAPORATOR

Fig 7 is a graphical log of a typical test of Professor Kerr. The complete figures for the different tests are given in form of tables in the original paper.

DEFINITIONS

It is customary to make evaporator guarantees on a basis of 75 per cent evaporation by volume. As the initial and final densities of the juice are seldom such as to give exactly 75 per cent evaporation, it is necessary to determine the "equivalent volume of juice in gallons per 24 hr." by calculation. There seems to be no standard unit for rating evaporators. Sometimes an evaporator is guaranteed to handle a stated number of gallons of juice per 24 hr. with 75 per cent evaporation, nothing being stated as to the temperature of the juice; in other cases the temperature of the juice is specified. Probably the best standard rating would be "equivalent gallons of juice handled per 24 hr. with 75 per cent evaporation." Primarily a multiple evaporator is supposed to evaporate and not heat; actually, however, the juice may enter the first body at a temperature lower or higher than that of boiling.

The method of calculating the "equivalent juice treated with 75 per cent evaporation" is illustrated by a numerical example in the original paper.

The term *thermal efficiency* is used to indicate the heat efficiency of the evaporator as a whole. It may be

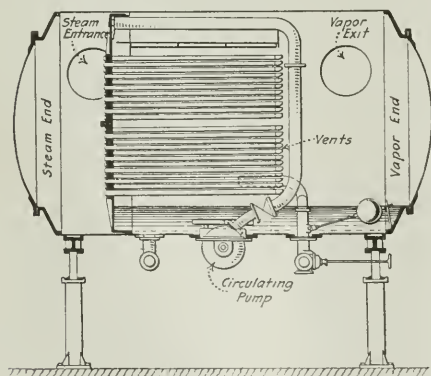


FIG. 3—ONE BODY OF TYPE C EVAPORATOR

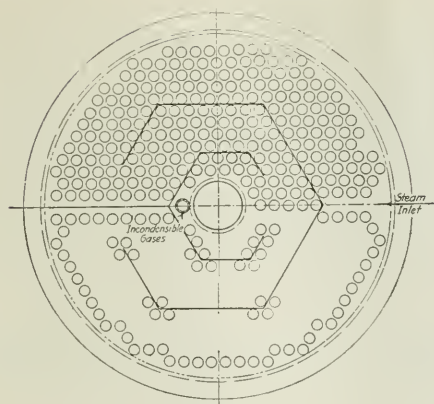


FIG. 5—STEAM DISTRIBUTION (TYPES E AND F EVAPORATORS)

determined by dividing the actual weight of water evaporated per pound of steam supplied by the theoretical weight of water that would be evaporated per pound of steam supplied were there no heat losses. The method of calculating the thermal efficiency is illustrated in Professor Kerr's paper by a numerical example.

HEAT TRANSMISSION TESTS

The coefficient of heat transmission, the B.t.u. transmitted per square foot of heating surface per hour per degree difference in temperature, is obtained for each body by dividing the heat in British thermal units transmitted during the test by the number of hours, by the number of square feet of heating surface and by the apparent temperature fall in that body. As the apparent temperature fall is used, the coefficients are termed "apparent."

The results are given in the paper in tables and diagrams. In general, the heat transmission coefficients of the evaporators in actual sugar-house practice were found to be smaller than the coefficients in former determinations in laboratory tests. This is doubtless due among other things to the fact that the heating surface in the laboratory apparatus was always clean, while in the sugar houses the tests were made in nearly all cases without special preparation, the time since cleaning, etc., varying considerably. It is interesting to note, however, that the coefficients obtained are higher than with ordinary surface condensers and equally as high as with modern types of high-vacuum surface condensers.

Typical curves are given in the paper for the heat transmission coefficients of the different types and comparative curves for types A, B, C and D evaporators are reproduced in Fig. 8.

Table I gives the average, maximum and minimum coefficients for each type taken from the same tests. The highest actual coefficients were obtained from type F (atmospheric double effect). These high coefficients were doubtless due to the high steam pressure and the corresponding high density of the steam. As apparent temperature fall was used in determining the coefficients, they not only indicate the relative heat transmitting ability of the heating surface in the different types, but include also the effect of peculiarities due to type, such as hydrostatic head, method of removing condensation, method of venting, etc. The film evapora-

TABLE I—COEFFICIENT OF HEAT TRANSMISSION (Actual)

Type	Average	Maximum	Minimum	No. of Tests Included in Average	Relative Coefficient (Actual) = 100	Relative Coefficient (Corrected) Standard = 100
A	197	289	172	7	100	100
B	213	291	130	5	108	74
C	392	449	334	3	199	160
D	266	353	190	6	135	119
E	248	284	190	3	126	180
F	503	509	498	2	255	131
G	293	...	...	1	149	139

tors (types C and D) gave coefficients considerably higher than did the submerged tube types.

Comparing types A and B, the latter has some advantage, the average actual coefficient for type B being some 8 per cent greater than the average for type A. The tests of type E show an average coefficient of 248, which is some 25 per cent greater than the average for type A. Comparing types C and D the average coefficient for the former is 392, which is some 47 per cent

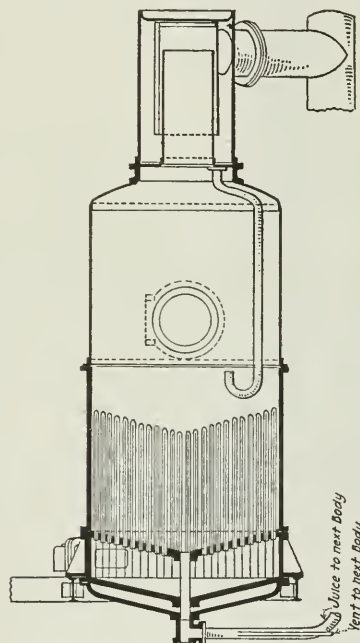


FIG. 6—DOUBLE TUBE EVAPORATOR (TYPE G)

greater than that of the latter. Type C requires centrifugal circulating pumps for handling the juice, something not required by other types. Tests of motors driving these pumps showed 0.1 hp. per 1000 gal. of juice treated per 24 hr. This should be kept in mind in comparing this type with others. Only one test was made upon type G and this under conditions which could hardly be called favorable, the amount of juice supplied being far below its rated capacity and the juice head greater than would have been used had it been operated with an amount of juice nearer its normal capacity.

With type A only four evaporators out of a total of eleven gave coefficients above 200. In these four the conditions of operation were fair as regards cleanliness, drainage and venting. The number of days since clean-

ing is given for each test, though this can hardly be relied upon to give an accurate idea of the condition of the heating surface, for the reason that all of the evaporators had not been cleaned with equal thoroughness. In practice, the time consumed in boiling out, also the strength of the soda and acid, vary greatly. In some cases, the thoroughness of cleaning is not sufficient to prevent a progressive fouling of the heating surface toward the end of the season.

Practically all of the tests on type A were made with very low steam pressure in the first body, usually near atmospheric pressure, and in some cases, less than atmospheric pressure. With most of the other types, the pressure was higher, which puts type A at a disadvantage in making comparisons with the average coefficients given. On the basis of laboratory tests a correction was made and the *corrected* coefficients are given in the last column of Table 1. These *corrected* coefficients may perhaps give a better means of comparing types than the actual coefficients, especially as regards types A and B. However, too much dependence should not be placed on these corrected coefficients, as the correction formula was determined from laboratory experiments.

RATE OF EVAPORATION

The unit "pounds of water evaporated per square foot of heating surface per hour" is convenient for rating evaporators, and is fairly satisfactory provided the steam pressure and the vacuum do not vary greatly. The *actual* values do not furnish a fair comparison on account of the widely varying steam pressure and vacuum. An attempt has been made by the author to determine the equivalent evaporation that would have resulted had all tests been made with a steam pressure of 5 lb. gage in the first body and a vacuum of 26 in. in the last body.

These corrected values for the average pounds of water evaporated per square foot of heating surface per hour are for type A quadruple 6.18, A triple 9.2, A

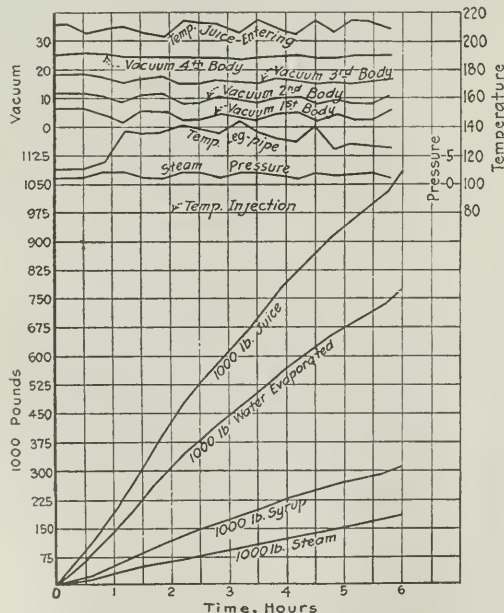


FIG. 7—GRAPHICAL LOG OF TYPICAL EVAPORATOR TEST

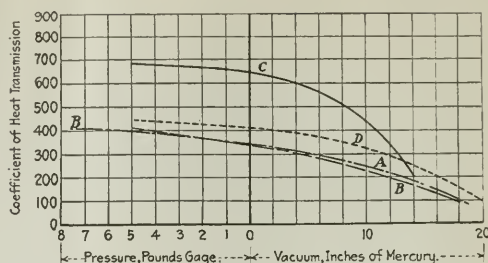


FIG. 8—COMPARISON OF HEAT TRANSMISSION COEFFICIENTS, TYPES A, B, C AND D EVAPORATORS

double 16.7, B quadruple 4.55, B triple 11.49, C quadruple 11.05, D quadruple 10.05, D triple 9.21, E triple 16.93, F double 17.4, and G quadruple 9.67.

THERMAL EFFICIENCY

Figures for "thermal efficiency" are finally given by Professor Kerr, after discussing losses due to radiation, losses due to vents, the effect of the method of handling the condensed steam (method *b* of those enumerated on page 606 being considered the most economical), etc.

The figures for thermal efficiency vary from a minimum of 85.06 to 98.3, the average being 94 per cent. The table in the original paper of Professor Kerr shows that the efficiency of type C was higher than type D, although the water evaporated per pound of steam supplied was greater in the latter than in the former. This apparent contradiction is due to two things: (1) the temperature of the juice entering the first body in the tests on type D was higher than in those on type C, more steam being required for heating in type C; (2) the condensation in type D was taken from body to body, beginning with the second, whereas it was drained away separately from each body of type C.

The table also emphasizes the importance of heat insulation and the effect of high rates of evaporation in increasing heat efficiency.

Recent Chemical and Metallurgical Patents

Iron and Steel

Cooling Exhaust End of Open-Hearth Furnace.—An arrangement of an open-hearth furnace designed to lengthen the life of the furnace ends by cooling them when subject to the action of the hot exhaust gases is patented by REGNIER EICKWORTH of Dortmund, Germany. Channels are arranged in the crowns of the furnace ends and connected with a compressed air conduit. The compressed air cools the crown, and passing into the exhaust channels a cooling effect results there. In order that the compressed air shall pass into the exhaust gases both ends of the furnace must be provided with channels and connected to a common compressed air line, which has a reversing valve at the junction. When the furnace gases are reversed the compressed air is reversed, the air-reversing gear being preferably connected to the furnace-reversing gear. The inlet end of the furnace thus does not receive any cooling. (1,176,744, March 28, 1916.)

Electrolytic Iron from Pyrite.—Sulphide ores of iron have not had commercial importance as sources of metallic iron, but have been treated mainly for the production of sulphurous and sulphuric acid, or for such other precious or base metals as the ores may contain.

The subject of a patent granted to AXEL ESTELLE of Hagen, Westphalia, Germany, is the treatment of pyritic iron ores for the production of electrolytic iron and pure sulphur. The process consists in first leaching the raw ore with weak non-oxidizing acid and precipitating the iron electrolytically with insoluble electrodes, a suitable method being employed for regenerating the solution. The steps of the process are shown in Fig. 1. Pyrite is first subjected to distillation without access of air, as in an electric furnace, for the sublimation and recovery of sulphur; or a smelting process may be conducted to render the iron in acid-soluble form and at the same time recover any valuable metals contained in

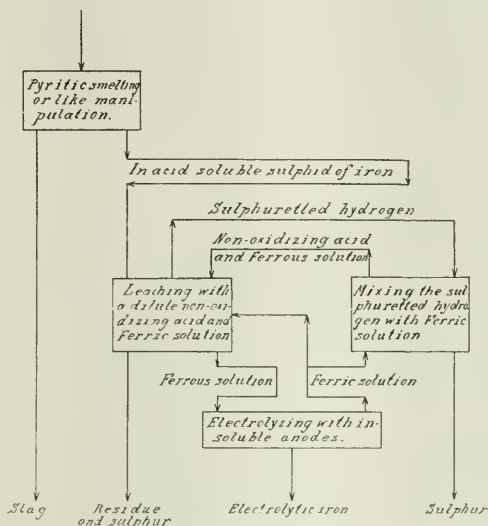


FIG. 1—ELECTROLYTIC IRON FROM PYRITIC ORE

the ore. The iron product is then treated with hydrochloric acid, yielding ferrous chloride and hydrogen sulphide. In the subsequent electrolysis a part of the iron is deposited while twice the amount is converted into ferric chloride. The latter is then passed, together with an equivalent quantity of hydrogen sulphide, into an absorption tower where the reaction yields ferrous chloride, hydrochloric acid and sulphur. The solvent thus regenerated is used again on fresh ore. (1,162,150, Nov. 30, 1915.)

Gold and Silver

Improved Process of Cyaniding.—With a view to increasing the efficiency and reducing the expense of cyaniding gold and silver ores, HARAI R. LAYNG of San Francisco, Cal., has patented a process of treatment. The principal object of the procedure is to minimize losses of cyanogen by conducting the treatment wholly or in part in closed vessels, and to provide means for recovering cyanogen now lost through volatilization or undesirable combinations with metals other than those sought, as well as from discarded residues and waste solutions. The patent specifications are lengthy and in considerable detail, and should be consulted by those interested in the subject. (1,178,081, April 4, 1916.)

Agitating and Settling Tank.—An agitator suitable for the treatment of slime pulp in the cyanidation of ores is patented by JOHN E. ROTHWELL of Butte, Mont., and assigned to the Colorado Iron Works Company, Denver. Combined with the agitator is means for simultaneously withdrawing clear liquid while agitation

is in progress, and for withdrawing from the tank at a point above the pulp level a portion of the pulp under treatment. The apparatus is shown in Fig. 2. It consists of a cylindrical tank with conical bottom, with a central air-lift for circulating pulp. Within the cylindrical portion is an annular partition or skirt 3, which provides a quiet settling zone from which clear solution can be withdrawn while agitation of the balance of the pulp is in progress within the partition. The air-lift elevates the mixture that settles at the bottom of the cone, as well as that part of the pulp which settles between the outer and inner pipes of the central column. The discharge is made over a flanged plate above the surface of the pulp, falling into the zone within the partition 3. A portion of the elevated mixture is cut out by the sampling vane 11 for transfer to another agitator or vessel. (1,179,658, April 18, 1916.)

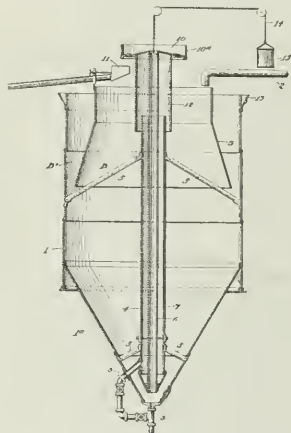


FIG. 2—AGITATING AND SETTLING TANK

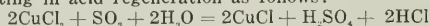
Method and Apparatus for Desulphurizing Refractory Ores.—A wet process of desulphurizing gold and silver ores to make them more amenable to cyanidation is the basis of patents granted to EDWARD H. DICKIE of Goldroad, Ariz. The apparatus consists of a filter-bottom tank in which are suspended air-lifts that can be moved in circular paths through the pulp. The air-lift pipes have linings and coverings of aluminium, which react with the ore and the caustic soda solution in which it is ground. When the tank is used as a filter, the air-lifts serve to keep the solids in suspension and prevent their accumulation on the tile bottom. (1,177,394-6, March 28, 1916.)

Copper, Lead, etc.

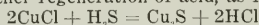
Electrolysis of Copper Leaching Solutions.—According to methods disclosed in a patent granted to WILLIAM E. GREENAWALT of Denver Col., the usual difficulties attending the electrolysis of sulphate solutions from copper leaching can be overcome. The difficulties have been due to (1) the insoluble anode, (2) electrode inefficiency due to useless oxidation and reduction, and (3) fouling of the electrolyte. Oxidation and disintegration of the lead anode has been an obstacle to successful electrolysis, the presence of ferric sulphate has caused redissolution of deposited metal, and the accumulation of impurities in the electrolyte has resulted in deposition of impure metal and in poor leaching. The inventor claims to have overcome these troubles in a large degree. He uses a diaphragm cell, with the copper solution as catholyte, and either depleted cathode solution or acid wash water from the treated ore as anolyte. Both solutions are preferably saturated with sulphur dioxide. In operation, while copper is deposited at the cathode, acid solution is regenerated at the anode, so that the catholyte can be wasted without perceptible loss. The diaphragm and a continually changing anolyte prevents the ferric sulphate from coming in contact with deposited copper, while in the presence of sulphur

dioxide an excess of acid is regenerated. Only a minimum amount of lead is peroxidized—about 1 ounce of lead per pound of copper deposited—and this is automatically removed. Impurities in solution can be kept down to limits that do no harm, as determined by experiment, by regulating the quantity wasted. (1,179,522, April 18, 1916.)

Hydrometallurgy of Copper.—A process of leaching copper ores with an acid chloride solution, precipitating the copper with hydrogen sulphide and subsequently electrolyzing the copper sulphide, is patented by WILLIAM E. GREENAWALT of Denver, Col. The metal is leached from the ore principally as cupric chloride and the solution is treated with sulphur dioxide, resulting in acid regeneration as follows:



The copper is then precipitated by hydrogen sulphide, with the further regeneration of acid, as follows:



Three molecules of acid are regenerated by sulphur dioxide and two by hydrogen sulphide, which is two and one-half times as much as would result if the original solution were precipitated directly with H_2S .

The precipitated copper is now in the form of pure sulphide without contamination with iron, and may be electrolyzed as anode without danger of fouling solutions. The power required is materially less than when copper is deposited from its solutions with insoluble anodes. (1,180,844, April 25, 1916.)

Leaching Copper Ores with Aluminium Sulphate Solution.—A proposed method for extracting copper from its ores is patented by EUGENE ERDŐS of Kolozsvár, Austria-Hungary, based on the use of solutions of aluminium sulphate, with a method for regenerating the solvent. Sulphide combinations of copper must be first roasted to oxide, but oxidized and carbonate forms are directly amenable. In the course of the treatment, basic salts of copper and aluminium are formed which are subsequently broken up by sulphuric acid, with the regeneration of aluminium sulphate. The separation of copper from the solution can be accomplished by evaporation and fractional crystallization. Copper sulphate is soluble at 70 deg. C. in a quantity of water equal to its own weight, while aluminium sulphate remains in solution in its own water of crystallization. (1,162,044, Nov. 30, 1916.)

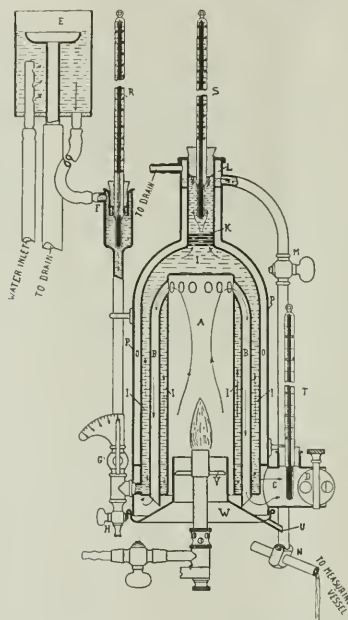
Precipitating Apparatus for Copper Solutions.—As a compact form of precipitating apparatus, in which copper sulphate solutions can be treated with scrap iron, JOSEPH IRVING, JR., of Douglas, Ariz., patents the use of a Dorr thickener of special construction. The patent is assigned to the Dorr Cyanide Machinery Company. The apparatus consists of a circular tank in which is a support for the iron precipitant. The pregnant solution enters the tank through a central well that extends below the support, and flows upward through the pieces of iron. The copper precipitate scales off from the iron and falls to the bottom of the tank, where it is removed to a central point by the rakes and discharged. The spent solution overflows at the periphery of the tank. (1,177,109, March 28, 1916.)

Construction for Electrolytic Vat.—A type of vat suitable for leaching copper ores or electrolyzing copper sulphate solutions is patented by HARRY H. STOUT of New York City, the patent being assigned to the Nichols Copper Company of New York City. The vat is rectangular and built of brick laid in cement mortar and reinforced with iron plates and rods. On the interior surface the mortar is recessed and the space filled with a priming coat of an organic substance dissolved in a volatile medium, such as asphalt and gasoline. A second coating is applied over the entire interior sur-

face, consisting of commercial asphaltum. This coating should be composed of material having a melting point below 300 deg. Fahr., and should not flow from position at or below 135 deg. Fahr. A vat thus constructed is resistant to the attack of acids or accidental blows. (1,169,205, Jan. 25, 1916.)

An Industrial and Laboratory Gas Calorimeter

A gas calorimeter apparatus for determining exactly and quickly the heating value of gases and liquid fuels, which is smaller than the standard form of gas calorimeters, is made by Wm. Gaertner & Co., 5345 Lake Park Avenue, Chicago, Ill., under the name of the Scientia calorimeter. The calorimeter is of the Junker type and its present form has been developed after considerable research work and experimenting. The com-



CROSS SECTION OF CALORIMETER

plete outfit consists of the Junker calorimeter body, constant level water tank, thermometers, burner, two nicked weighing pans, gas meter, gas pressure regulator, platform balance, and set of weights.

The calorimeter is shown in cross-section in the accompanying illustration. The following letters explain the diagram: A combustion chamber, B condenser tubes, C outlet for exhaust, D damper for exhaust, E inlet overflow weir, F water inlet, G inlet water valve, H drain cock, I water space, K mixing device, L outlet overflow weir, M shut-off cock, N change over device, O air space, P outer casing, R inlet water thermometer, S outlet water thermometer, T exhaust thermometer, U condensate drain, V centering device for burner, W detachable exhaust chamber. The heat of the gas to be measured is imparted to a stream of water, and the amount of water flowing through the calorimeter in the time that a known volume of gas is burned in the calorimeter and the resulting change in temperature of the water, furnish the necessary data for calculating the calorific value of the gas. The calorimeter vessel and inlet water tank are supported on a rod and tripod.

Quartz Resistance Thermometers

The increasing tendency toward the use of multiple recording thermometers and pyrometers for many industrial purposes has created a demand for measuring instruments for long-distance work. Thermometers of this class working on the electric resistance system are made by the Hanovia Chemical & Manufacturing Co., Newark, N. J. These are known as Heraeus quartz resistance thermometers.

The complete apparatus consists of the thermometers, connecting leads, battery, and an indicator mounted on a switchboard panel on which is also a series of buttons, which when pressed one at a time record the temperature at the different points where the thermometers are placed. A sliding rheostat for adjustment of the battery voltage is also placed on the switchboard, for correcting the zero point of the indicator dial.

The thermometers are made on the Wheatstone-bridge principle, having three known resistances whose values do not change with the temperature, and a fourth resistance of chemically pure platinum wire which forms the actual measuring element. The spirals are wound on fused quartz tubes 3 mm. and 6 mm. long. These are again enclosed in outer quartz tubes, hermetically sealed by fusion. The fused quartz remains unaffected by violent temperature fluctuations, and protects the platinum spool against deterioration.

For scientific work a transparent quartz tube is joined to the resistance unit and no protection tube is necessary, but for industrial purposes a more rugged mounting of double steel rods is used. Protection tubes may be of iron, steel, copper, nickel, lead or silica, depending on conditions under which the thermometer is to be used.

The indicators are highly sensitive galvanometers moving on a graduated scale. The scale limits may be —200 deg. C. to +700 deg. C., or may have a smaller range. By combining thermo-electric pyrometers on the same switchboard and equipping the indicator with an additional scale, the upper limit may be extended to +1600 deg. C.

Instead of the indicating instruments described, continuous recorders are also furnished.

Improvements in the Technique of Brinell Hardness Determinations

The application of the Brinell method of determining the hardness of metals—adopted as “standard” by the American Society for Testing Materials and the Society of Automobile Engineers—has so far been limited by three causes:

First, no device was formerly available for application of the Brinell principle which could be used for tests at any chosen spot of a large mass of metal (such as large castings, etc.), for tests on metal products of irregular shape, and on hollow metal bodies.

Second, thin metal sheets (of iron, copper, brass, aluminium, etc.) could not be tested heretofore by the Brinell method, because the 10-mm ball would quickly penetrate the thin metal section on account of the high pressure applied.

Third, no apparatus working on the Brinell principle had formerly been designed which could be carried around (by metallurgists, testing engineers, steel inspectors, steel salesmen, etc.), weighing not more than, say, 7 lbs.

Another important point often overlooked is that a “specimen” cut from the metal to be tested does not always represent the true average hardness of the entire mass under investigation. In metal products like car

wheels, rails, etc., considerable differences often appear in the hardness of the various sections.

All these difficulties have been overcome by the development of the “Brinell Meter,” designed and patented by the Metallurgical Department of the Standard Roller Bearing Company. In this portable apparatus a 10-mm nickel steel ball is simultaneously brought into contact on one side with the metal under investigation, and on the other side with a bar of known Brinell hardness. It will be readily understood that any pressure applied to the assemblage presses the ball with exactly the same force into the metal of unknown hardness as into the metal of known Brinell hardness. The Brinell hardness of the two metals is in direct relation to the proportion of the two indentations, varying directly as the spherical areas of the two impressions, consequently varying directly as the squares of the diameters of the two indentations. On this basis, direct-reading Brinell hardness tables have been worked out which are furnished with each instrument.

Since the “standard bars” furnished have four machined surfaces $6 \times 1\frac{1}{2}$ in., which can be ground off and can be used several times over, each bar can be utilized for several hundred tests. In this way, the cost of each Brinell test is much smaller than with the Brinell machine, eliminating the time and work of “cutting the specimen.” The measuring range of each standard bar is quite large, as the determination depends on the proportion of the two indentations; a standard bar of No. 250 Brinell hardness, for instance, serves conveniently for Brinell tests from No. 180 to No. 330 Brinell units. Brass bars of known Brinell hardness can be supplied for Brinell tests on brass, copper, aluminium, etc.

The more important advantages of the new “Brinell meter” may be summarized as follows:

The Brinell method is made independent of the dimensions, shape, and location of the metal mass under investigation.

The “sampling error” in cutting specimens for tests in the Brinell machine is eliminated, as the instrument can be applied to any chosen spot of a large mass of metal, horizontally as well as vertically.

Metals of great softness can be tested just as ac-



THE BRINELL METER

curately as metals of usual hardness; thin sheets can be tested just as well as thick sections.

The complete Brinell meter outfit, in carrying case, only weighs 6½ lb., so that it can be conveniently carried around the plant by the metallurgist or engineer of tests; it can be taken on trips by salesmen and trouble investigators employed by the steel companies, etc.

The apparatus is simple in construction and is easily applied; any workman of average intelligence can now make accurate Brinell tests. No part of the instrument can get out of order.

The complete outfit is low in price, so that metallurgical plants can easily afford to have a number of them around the shops, the foundry, the forging plant, the rolling mill, the laboratory, etc.

The Brinell meter, protected by patents on the method of determination and on the construction of apparatus, is manufactured, under sole license agreement, by Mr. Herman A. Holz, 50 Church Street, New York.

A Portable Hydraulic Hardness Testing Machine

For a number of years the metal industries of the United States and other countries have been seeking a method of securing definite and accurate determinations for hardness of metals to take the place of the so-called comparative tests made with a number of instruments.

Practically all testing engineers and metal workers have been making investigations relative to hardness measurements with little definite success, until the introduction of the Brinell method, which has been used

in various ways with such success that it is now recognized universally as the standard, because the results obtained by its use can absolutely be depended on. For this reason the application of this method is especially valuable for structural material, rails, automobile parts, etc., and for ascertaining the effects of annealing and hardening of steel.

A hydraulic hardness testing machine of the Brinell principle has been manufactured by the Pittsburgh Instrument & Machine Co., Pittsburgh, Pa., for several years; it is a compact apparatus and its construction such that it brings results. These machines are of heavy construction, which makes it necessary to place them permanently and carry all test pieces to the location of the machine.

Numerous firms have made inquiries for a portable instrument, one that can be carried to the point where the materials collect. In order to meet the demand for such an instrument the Pittsburgh Instrument & Machine Co. has designed a hydraulic hardness testing machine of the Brinell principle which can be carried from one location to another by one man.

The working mechanism of this new apparatus has been somewhat reduced, but the change has been accomplished without reducing the general efficiency shown by the larger type machine.

The accompanying illustration shows the smaller apparatus.

Industrial Notes

Metric System in Denmark.—According to Commerce Reports the American Consul at Copenhagen, Denmark, reports that beginning with April 1, 1916, the old system of the pound in weights and the alein in measurement was discontinued and the metric system adopted. All dealers in goods sold by weight are now required to sell them by the kilogram or meter.

Chemicals from Great Salt Lake.—The Salt Lake Chemical Company has been incorporated to extract chemicals from the waters of the Great Salt Lake at Grants, Utah. The chief constituent is common salt.

Electrolytic Bleaching Plant.—A plant for the electrolytic bleaching of sulphur pulp will be erected by the Eastern Chemical Company, South Brewer, Me.

The Laboratory Supply Co., Columbus, Ohio, has issued a catalog of its special "made in America" laboratory supplies, including porcelain, glassware, rubber goods, and other materials.

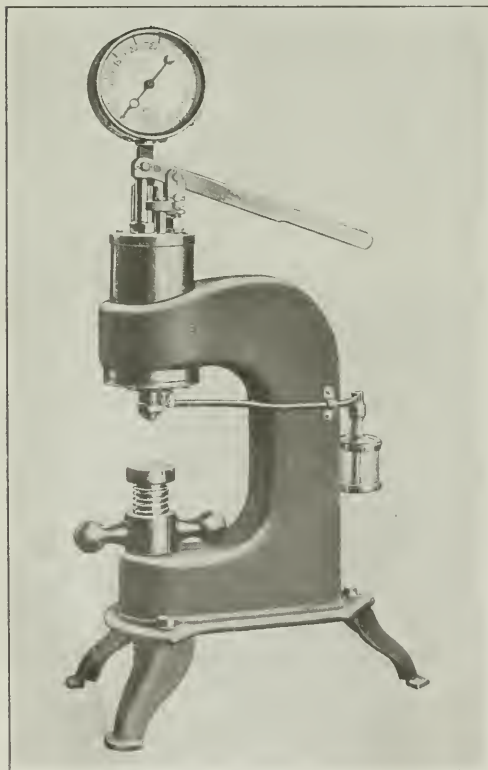
Production of Coal-Tar Products.—According to Commerce Reports the estimated production of coal-tar crudes in the United States is at present at the following annual rates: Benzol, 90,000 tons; toluol, 22,440 tons; naphthaline, 12,500 tons; phenol (chiefly synthetic), 10,000 tons.

The Seaboard By-Product Coke Company is erecting a 110-oven by-product coke plant at Jersey City, N. J. The plant is being built by the H. Koppers Company, Pittsburgh, Pa.

The Combustion Engineering Corporation, 11 Broadway, New York, has moved its offices from the thirteenth floor to larger offices on the eighth floor in the same building. The increase in business in the last four years has made necessary an increase in office space of five times the amount occupied in 1912.

The Union By-Product Coke Company, Buffalo, has begun the erection of a by-product coke plant to cost, with the land, \$1,800,000. Westinghouse, Church, Kerr & Co., are supervising the construction while the actual work is in the hands of the American Coal & By-Products Coke Company.

The second annual edition of the **Zinc and Lead Handbook**, published by the Joplin News-Herald, has



HARDNESS TESTING MACHINE

been issued recently. This useful little book, edited by L. L. Wittich, contains much information compiled from various sources on zinc and lead in the Joplin district, together with a map of this district, and other general information on these two metals.

The Schutte and Koerting Company, Philadelphia, Pa., has issued additions to its catalog as follows: Catalog 8, Section L, describing lead lined valves and Catalog 7, Section L, describing hard lead and rubber fittings.

The Goldschmidt Thermit Co., New York City, announces the removal of its main office to the Equitable Building, 120 Broadway.

The Sarco Company, Inc., Woolworth Building, New York City, has issued a little booklet on Sarco temperature control, which explains the operation of its temperature regulators, for tanks, containers, rooms, etc. The regulators control automatically the temperature of air, or any gas or liquid.

University of California Establishes Course in Chemical Engineering.—Chemical engineering is to be established as a separate new course in the University of California. In the junior year the course will include studies in organic and physical chemistry, steam engineering, hydraulics, advanced physics and economics. The senior year will be devoted to the study of organic and technical chemistry, thermo-dynamics, applied electro-chemistry, laboratory training in experimental engineering in water, steam and gas engines, and work in the field of electrical machinery.

The Electric Smelting & Reduction Co., Portland, Me., has been incorporated to conduct a general mining, smelting and refining business. The capital stock is \$150,000.

Lead as Substitute for Galvanizing.—The Ledcote Company of Canada, Ltd., Amherst, N. S., contemplates the erection of a plant for covering sheets with lead as a substitute for galvanizing.

The Sweetland Filter Press Co., Inc., announces that owing to increasing business it has leased the entire floor of the new Sperry building, 36 Flatbush Avenue Extension, Brooklyn, and that its offices, laboratory and test plant were removed to that address on May 1.

The Doehler Die-Casting Co., Brooklyn, N. Y., announces that it has acquired a controlling interest in the American Die Casting Co., of Newark, N. J., which will hereafter be known as the Doehler Die-Casting Co. of New Jersey.

Industrial Exhibition in Jersey City.—The manufacturers and retail merchants of Jersey City are co-operating in an industrial exhibition of Jersey City made goods, to be held June 5-10. This exhibition will differ from the general run of industrial displays in the fact that instead of grouping the exhibits in any one hall or building, each retail merchant will turn his store into a show room for some particular manufactured article, which is made in this city and which he can commercially handle.

New Molybdenum Smelting Plant.—The International Molybdenum Co. has been incorporated in Canada and contemplates the erection of a smelting plant at Renfrew, Ontario.

The Aetna Chemical Company of Canada, Ltd., will erect a \$300,000 sulphuric acid plant at Drummondville, Quebec. The construction work is in charge of Westinghouse, Church, Kerr & Co., New York City.

The Consolidated Mining & Smelting Company is erecting a sulphuric acid and hydrofluoric acid plant at its smelter at Trail, B. C.

The Chicago Pneumatic Tool Co., has issued bulletin No. 34-Q, describing applications of Giant gas and fuel oil engines.

Chromic Iron Ore.—The production of chromic iron ore or chromite in the United States in 1915 was 3281 tons, valued at \$36,744, according to the Geological Survey report of J. S. Diller. This was a gain of 2690 tons over the 1914 production. The output came entirely from California.

Antimony.—The Magnolia Metal Co., is producing a small quantity of antimony from its new smelting plant at Matawan, N. J. This is the only plant on the Atlantic Coast smelting antimony.

The Liberty Bell Mine Crew was given its second safety-first dinner on April 7, 1916, at Telluride, Col. This is the second year since the crew was formed without fatal accident and with few serious mishaps, and the dinner was given in recognition of this achievement.

The Quigley Furnace Specialties Company has been formed with offices at 26 Cortlandt Street, New York City, Mr. W. S. Quigley being the president. All the members of the organization have had years of experience in specializing in the fuel and furnace line. The "furnace specialties department" will manufacture and deal in a line of high-grade furnace materials, equipment and appliances for the improvement of furnace construction, operation and methods, such as high-temperature furnace cements, insulating brick, automatic fuel-oil valves, oil, gas and powdered-coal burners, temperature and draft-recording and controlling systems, gas-analyzing instruments, etc. The "engineering and contracting department" is prepared to analyze and compare the operating costs of powdered coal, hand or stoker-fired coal, gas and fuel oil, make recommendations as to the most economical fuel and its applications and furnish complete plans, specifications and supervision for the entire installation of any fuel.

Courses in Foreign Trade Announced

Dr. Edward E. Pratt, Chief of the Bureau of Foreign and Domestic Commerce of the United States Department of Commerce, is the director of an educational course in foreign trade which has just been announced. Associated with Dr. Pratt in the preparation of the course are men prominent in American export activities, including O. P. Austin, of the National City Bank of New York; E. N. Vose, editor of *Dun's International Review*; E. A. De Lima, president of the Battery Park National Bank of New York; Prof. Emory R. Johnson and Dr. G. G. Huebner, of the University of Pennsylvania, and several others. The course in foreign trade is designed to aid manufacturers, banks, export houses and other concerns in giving adequate training to the men in their organizations who are handling or may be developed to handle their foreign business. The course covers a treatment of the various factors entering into export marketing, such as world trade economics, export policies, export houses, direct exporting, the export salesman, shipping, financing, export technique, foreign and home law, and importing. The course is being issued through the Business Training Corporation, with offices at 185 Madison Avenue, New York.

Personal

Mr. Warren P. Blauvelt has been engaged by the Steere Engineering Company, Detroit, Mich., to devote his entire time to the company. He will give special attention to plant design and the solution of operating problems, and to the improvement of apparatus and methods in the gas industry.

Mr. Alexander C. Brown, formerly vice-president, has been appointed general manager of The Brown Hoisting Machinery Company, Cleveland, Ohio, succeeding Mr. Richard C. Sheridan, who has resigned to accept another position.

Mr. A. E. Drucker has completed his work at the Frontino-Bolivia mill in Columbia, and expected to sail from New York for London on the 11th inst.

Mr. W. E. Gray, Jr., representing the Elyria Enamelled Products Company in the Pittsburgh district, has opened an office for the company at 1237 Oliver Building, Pittsburgh.

Mr. Geo. H. Higgins has been appointed factory manager of the Burd High Compression Ring Company, Rockford, Ill. He was formerly associated with the Stone & Webster Corporation, the Westinghouse Electric & Manufacturing Company, and several motor car companies.

Mr. Alonzo G. Kinyon, superintendent of locomotive operation on the Seaboard Air Line Railway for a number of years, has resigned this position to become chief consultant of the board of engineering research power generation in steam locomotives for the Powdered Coal Engineering & Equipment Company, Chicago. Mr. Kinyon's knowledge of locomotive combustion, drafting and fuel economy tests began when a young man as locomotive fireman on the Chicago, Milwaukee & St. Paul Railway, and for the last twenty-eight years he has done nothing else but burn coal as a fuel. For a number of years he was advisory consultant of combustion for the International Correspondence School of Scranton. He is at present vice-president of the Traveling Engineers' Association and a member of the executive committee of the International Railway Fuel Association.

Dr. Julius Koebig, consulting chemical and mining engineer, announces the removal of his office to 329 Union Oil Building, Los Angeles, California.

Mr. E. A. Mitchell, president of The Wyckoff Pipe & Creosoting Company, Inc., New York City, has bought a large coal mine in Alabama on the Black Warrior River. This coal has been tested and found to be a much better coal than the Pocahontas. Mr. A. E. Mitchell, a well-known engineer, who is also an expert on coal values, states that this coal is one of the best for making coke. The company may also build coke ovens and chemical plant for making creosote oil and other byproducts.

Mr. H. W. Seldon, formerly assistant metallurgist of the Cambria Steel Company, is now in charge of the metallurgical department of the Scientific Materials Company, Pittsburgh, Pa.

Mr. J. E. Simpson will shortly open a Chicago office for the Elyria Enamelled Products Company, and will have charge of the company's business in that district. He may be addressed temporarily in care of the Morrison Hotel, Chicago.

Mr. James R. Stack, formerly chemist at the Perth Amboy plant of the American Smelting & Refining Company, has been appointed chief chemist of the Baltimore Copper Smelting & Rolling Company, Baltimore, Md.

Mr. F. R. Wadleigh, consulting engineer in coal and coke, announces the removal of his office to 1418 Walnut Street, Bellevue Court Building, Philadelphia, Pa.

Obituary

Lucien I. Blake, well known for his work in the field of physics and electricity, and particularly electrostatic ore separation, and as inventor of the submarine signal, died in Boston early in May. He was born in Mansfield, Mass., on Sept. 12, 1854. He received the degree of A.B. from Amherst College in 1877, was Tyndall fellow at Harvard 1881-83, and then went to Berlin, where he received the degree of Ph.D. in 1884. In 1884-5 he was assistant professor of mathematics at Adelphi College, from 1885 to 1887

professor of physics and electrical engineering at Rose Polytechnic Institute, and held the same position at Kansas University from 1887 to 1905. He left Kansas to go to Colorado and develop his electrostatic ore separator, which was subsequently introduced on a commercial scale for the separation of complex sulphide ores. His greatest invention was probably the submarine signal. He was chief engineer of the Submarine Signal Co., and director and engineer of the Blake-Morscher Electrostatic Ore Separating Co. Dr. Blake was married in Denver in the spring of 1911, and immediately went to Europe for several years. He was an excellent lecturer, and gave a summer course at Berkeley in 1914 on cosmic physics. Later the same course was repeated in popular form in Denver in the spring of 1915. He recently completed a condensed course on the same subject at Union Theological Seminary, New York. He was a member of the American Physical Society, American Electrochemical Society and American Chemical Society.

Book Reviews

Coal: Its Economical and Smokeless Combustion. By James F. Cosgrove. Octavo (13 x 21 cm.), 281 pages, 33 illustrations. Price, \$3.00. Philadelphia: Technical Book Publishing Company.

Intended to explain to the general public in clear, simple language the characteristics of various kinds of coal, so that they may be bought intelligently and burned economically and smokelessly. It contains much good practical horse-sense on the fuel question, and is well suited to its avowed purpose. The author slips up in some small details of the scientific aspects of the question, but the faults are minor ones.

Lehrbuch der Eisenhüttenkunde. Vol. I: Roheisen-erzeugung. By Bernhard Osann. 15 by 23 cm. xiii + 668 pages, 17 tables, 407 illustrations; price 30.50 marks. Leipzig: Wilhelm Engelmann.

Professor Osann of the Mining Academy of Clausthal, well-known for his handbook on iron and steel castings, gives us here the first installment of a comprehensive work on iron and steel—The Production of Pig Iron. Volume II will treat of the manufacture of malleable iron and steel.

The work is painstakingly written, but somewhat labored. The author has the technique well mastered, but the general points of view from which the discussion proceeds are sometimes poorly chosen; for instance, the treatment of the efficiency of blast-furnace working from the standpoint of the "reduction figure"—a frequently faulty and altogether unsatisfactory criterion. In 1905 Professor Osann made a faulty criticism of the Gayley dried blast process, making erroneous calculations to substantiate his position, and although he has since been shown to be very far from right, yet the whole question of dry-blast is here discussed from the same erroneous standpoint, and not from the much better and more lucid reasoning from a critical smelting temperature, such as advanced by J. E. Johnson, Jr.

And so on, while leafing through the book, there are to be found reams of useful information, but also numerous points of theory or opinion which are doubtful or debatable, with the opposing views omitted.

If Ledebur's classic work is unfortunately becoming antiquated, then Professor Osann's work may have a *raison d'être*, but it is not yet its equal in judgment and breadth of view. Its principal value will be to inform readers on the *present facts* of the metallurgy of iron; but many of the author's theories and explanations need to be read critically.

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The Newlands Bill and Research

We have been very glad indeed to publish in our last issue and in the present one Dr. W. R. Whitney's two articles on the Newlands bill and research. As the distinguished chairman of the Chemistry and Physics Committee of the U. S. Naval Consulting Board, Dr. Whitney speaks authoritatively on the need of more research in this country. As the brilliant director of the Research Laboratory of the General Electric Company, Dr. Whitney is probably better fitted than any one else to say how research can be organized on a large scale so as to bring results.

We are very glad to see from Dr. Whitney's present article that representative scientific and technical men in this country are now expressing themselves practically unanimously in favor of the Newlands bill as the most sensible means of promoting research. To ourselves the feature which appeals most strongly in the Newlands bill is the logical manner in which the development of more research is to be attempted *ab ovo*, not starting at once with a big concentrated research institution, but with the creation of many nuclei of research spirit in the Land Grant Colleges all over the country. This country needs as much pioneer spirit to-day as in the days of our pioneer ancestors who founded this nation. But the pioneer spirit most needed to-day under changed conditions is of a different kind. Our country will take a good step forward toward the realization of its ideals, if the Newlands bill is adopted by an enlightened Congress.

The Chemistry of Flotation

The flotation process has been called a metallurgical anomaly, because it is so different from specific-gravity concentration. In ordinary water-concentration the lighter gangue is washed away from the heavier metallic particles, but in the flotation process the heavier metallic particles are floated. However, the "anomaly" is purely in the viewpoint of the millman who thinks of flotation in terms of specific-gravity concentration. He might just as well speak of electro-magnetic concentration as a metallurgical anomaly, whenever the magnetic particles are heavier than the non-magnetic particles from which they are separated. The fact is that in the flotation process an entirely new principle has been introduced into metallurgical practice which permits old things to be done in a new manner and which also permits a great many things to be done which could not be done before.

At the recent joint meeting of the New York Sections of the American Institute of Mining Engineers and of the American Electrochemical Society two very interesting papers were presented by Mr. George D. Van

Arsdale and by Prof. Wilder D. Bancroft on the how and why of flotation. Both papers were abstracted on page 572 of our last issue, and Professor Bancroft's paper is published in full on page 631 of our present issue. However they differed in the way of expressing their ideas, both authors were in complete harmony on all essential points and both discussed the how rather than the why of flotation. Mr. Van Arsdale defined flotation as that process of concentration which utilizes the different behavior of different kinds of solid particles with respect to surfaces of liquids and gases; flotation is surface action, and, such being the case, the chemistry of flotation must be closely allied with the chemistry of colloids. And exactly the same idea is expressed in Professor Bancroft's statement that ore flotation is not a unique phenomenon, but that it is merely a special case under the broad heading of emulsions. In laying so much stress on the many things which are analogous in one way or another to flotation, Professor Bancroft's paper should have the much-needed effect of dispossessing people finally of the idea that ore flotation is something unique in having laws of its own.

Whether one prefers to speak of the contact angle (as Mr. Van Arsdale does) or of the degree of wetting (as Professor Bancroft does), in either case the ultimate determining factor is the surface film on the particles. Both authors dealt at great length with this surface film. Mr. Van Arsdale pointed out that it may be either a solid or a liquid or a gas or an electrostatic charge or a combination of them. Professor Bancroft laid particular stress on the fact that in the surface film we have to do with selective adsorption. If a liquid wets a solid, it is adsorbed by the solid, forming a liquid film on the surface of the latter and displacing the air that was there. In many of the cases where oil flotation has been employed, the sulphide ore is more readily wetted by oil than water while the siliceous gangue is more readily wetted by water than by oil; consequently the gangue stays in the water phase while the ore is carried up by the oil. However, the problem of selective adsorption is here simply stated not solved; why are the sulphide particles more readily wetted by oil than by water? Nevertheless in some cases the adsorption-film theory brings us nearer to the why. If the surface of a copper wire be converted to sulphide, it will float more readily; we may simply state the fact and say that the contact angle is changed by the change to sulphide to facilitate flotation. Or we may go a step further with Professor Bancroft and say that the reason is that the adsorption of an air film is more marked with the change to sulphide.

The study of the selective adsorption of gases and vapors by solids and liquids will without doubt bring us in time much nearer to the discovery of some of the why's of flotation along the lines sketched by Professor Bancroft. And yet it must be doubted that it will supply the whole solution. The most open part of the whole theory is the question what part electrostatic surface films play in ore flotation, if any. There is no doubt that an electrostatic charge changes the contact angle in a definite manner; the capillary electrometer

would not be an exact measuring instrument otherwise. This is one firmly established fact. On the other hand, as J. M. Callow has pointed out (our issue of Jan. 1, 1916, page 49), there is a certain parallelism between electrostatic characteristics and the flotation properties of ores. Between these two sets of facts there is a wide gulf that needs to be filled. But from what we know of the electrostatics of colloids we may conclude that there must be some definite connection.

After all, the New York sections of the American Institute of Mining Engineers and of the American Electrochemical Society have done wonderfully well in getting together. If the pace set can be kept up, their annual joint meeting will become a classic event. Last year it was the Ricketts symposium on copper leaching; this year the Van Arsdale-Bancroft symposium on flotation. What next? The two sections did just the right thing in re-electing their respective chairmen, Dr. David H. Browne and Dr. Colin G. Fink.

Making Steel and Selling Steel

Not infrequently the steel works manager acquires a "grouch" against the sales department. He feels that the benefit of economies he has striven hard to effect are handed over to the buyer of the steel instead of being retained to enrich the company's treasury. Often there is reflection upon the sales department because it cuts a price a dollar a ton, perhaps several dollars a ton, when the works manager thinks in units of a cent or a tenth of a cent a ton.

It is natural for such criticism to go too far, through two points being overlooked. Whether the reduction in cost made by the works manager is given away by the sales department or not, the manager must introduce all the economies he can, for whenever he does not his works will begin falling behind. Another point is that a reduction in the cost of manufacture is a reduction per ton of output for an indefinite time in the future, whereas a cut price is only upon a limited tonnage. The aggregate value of a reduction of 10 cents a ton in cost of manufacture may be vastly greater than the aggregate loss of an unnecessary cut of \$1 a ton upon a specific number of tons involved in a given sale.

It is obvious, however, that operating departments are conducted more scientifically than sales departments. It is easier to see why this is the case than to see that it must always be the case. The difference in position is due to the fact that what is done in the operating department stays and must ultimately become public, while what is done in the sales department may be kept secret. Eventually it must be forgotten, while improvements in appliances and practices are to be seen and must eventually come to the knowledge of competitors. Knowing that his improvement must reach other works eventually, the works manager is frequently disposed to swap information, whereby both parties may gain.

Sales departments of rival producers do not correspondingly swap information. Occasionally they do make exchanges, but even then there is a tendency to withhold part at least of the truth. Statements with respect to sales cannot be tested for accuracy as well

as statements with respect to processes of manufacture, and the environments are such that circumstances compel works managers to be more accurate in their statements than is the case with sales managers.

There has been so much prosecution, and threat of prosecution, on account of alleged restriction in trade, that sellers of steel, as well as of other commodities, have become extremely reserved as to communicating with competitors. They have become unduly sensitive, because no clear guide was furnished as to what they were permitted to do and what they were not permitted to do. Of late, however, the situation has been growing clearer. The Department of Justice has approved certain practices, and the recently established Federal Trade Commission has been preaching co-operation among manufacturers. It is true this commission has no legal authority, but it has a great deal of influence. It is vigorously urging the adoption of more accurate cost accounting systems, for the direct guidance of those who make the sales and it strongly advocates trade associations.

The way is open, legally, for many reforms in sales methods, and it will be the fault of sales managers if the reforms are not effected. The real barrier at the moment is the indisposition to exchange information. In several branches of industry a system has been put in operation, with full sanction of the Washington authorities, whereby all sales of a given commodity are reported to a commissioner, who in turn circulates the reports to the contributors. The practice, where tried, has proved profitable to the participants, and it can be adopted in almost any branch of industry when the individuals are willing to participate. Another system of publicity which has proved efficacious in improving sales methods has been that of comparing production costs, whereby a composite cost of manufacture in a branch of industry is obtained. These methods employ psychology rather than force to improve sales practices. They enlighten sellers and remove misapprehensions. The sales manager, for instance, may have been disposed to ignore his own costs on the assumption that competitors had lower costs which he had to meet. Knowledge that those costs are not as low as surmised has often led to sellers demanding higher prices or refusing to make cuts, while knowledge that costs of competitors are lower leads to changes in methods of operation.

All this is enlightening publicity tending to improve sales methods. The selling of steel can be made more scientific and we believe it will be. The principle of exchanging information that has improved the industry of making steel must be adapted to the industry of selling steel.

All by the Way—of Three

Shakespeare once said, "All the world's a stage and the men and women merely players on it," and gave a list of the seven stages or seven ages of man. He brought in this way the mystic number of seven into his inventory of life. The ancients, too, delighting in a certain mysticism of numbers, placed astrological

importance on the numbers "seven" and "three." Numbers seem to be wonderful things on concepts, and the cardinal point is that numbers are cardinal and comprehend the idea of separate entities. In the red color there may be battle and blood, but, on the other hand, there is safety in cardinal numbers.

The number "seven" is then regarded as mystic, as is seen in the colors of the spectrum, but the number "three" is simple and is understood by men, for the human mind can grasp three things at one time, but not seven things. The old phrase, "The rule of three," we will see can be applied to many things besides arithmetic. Thus, we have a three-sided truss, the strongest mechanical configuration, and the three-phase current, the most stable "electrical structure." Let us just pause a moment in thought and consider how many triplets of verb, nouns, and adjectives we use in our ordinary and everyday life. Thus, in a business deal we have "discussion, negotiation, and execution." We "read, mark, and inwardly digest." A contract is "signed, sealed, and delivered." "Make ready, aim, and fire" is the martial order. Adjectives when strung in groups of three have a particularly sonorous sound and felicity of expression. Thus a man may be "good, bad or indifferent." In the nineteenth-century "twenty-question" game of children we all used to ask, first of all, "animal, vegetable, or mineral?" In grammar, too, we learned "past, present, and future."

We know that every human character and also human intelligence is derived from countless little, "see, think, and act" mental operations. Then we have the three dimensions of space, "length, breadth, and thickness." Indeed, if life is life, "all good things come in threes." And the music of the waltz pervades love. So things seem to repeat themselves to mankind by the simple number three. The "positive, comparative, and superlative" are likewise three-fold.

The three "R's," "reading, 'riting and 'rithmetic," are well known. Then, too, those that follow the sea must know the "three L's," "lead, latitude, and lookout." The keen sailor used the "lead" to sound the bottom, his reckoning of "latitude" to know where his boat is, and the "lookout" to see ahead.

The rule of the number "three" pervades life in some way, and we should "stop, look, and listen," so that some evil things we have done twice we will do not thrice, and so that the good thing that we've made a "duo" may be made a "trio." In the language of the old song "Learning Mulvaney to Waltz" we know: "Now, one, two, three, come balance with me, your left foot is lazy, your right foot is crazy, but don't be 'unaisy,' your learning to waltz."

Now, indeed, seriously, more seriously, and most seriously, to use ourselves the rule of three in learning to waltz in our minds, and to preserve an equilateral triangle of psychological forces, we become balanced and poised. "One, two, three, come balance like me," is the simple refrain of an Irish comic song, but it comprehends, broadens, and intensifies "the rule of three" expressed, a trinity of "labor, love, life" to those that know how to live simply, silently, and sarcastically.

Readers' Views and Comments

Questionnaire on Flotation

To the Editor of *Metallurgical & Chemical Engineering*

As regards the questionnaire on flotation which was published in your issue of May 15, page 562, Mr. J. L. Bruce, manager of the Butte & Superior Copper Co., has suggested that the following problems be added to the questionnaire:

1. Agitation as affecting static electricity upon the flotation of minerals.

2. Effect of heating on flotation pulp, conductivity, static phenomena, and surface tension.

3. Effect of acid or other electrolytes in creating galvanic action through contact with minerals or metals used in vessel or agitators.

4. Comparison of flotation results upon different ores as illustrated by comparative results upon different mesh sizes of the same ore.

We are very glad to receive these questions from Mr. Bruce and sincerely hope that those interested in the subject will give them careful consideration and discuss them in either the form of a paper, to be presented at the symposium at the Arizona meeting of the American Institute of Mining Engineers in September, or else present a discussion of them at the meeting, either in person or in writing.

DORSEY A. LYON.

University of Utah,
Salt Lake City, Utah.

Screamers

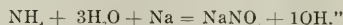
To the Editor of *Metallurgical & Chemical Engineering*

SIR:—The council of the American Chemical Society lately ordained that a committee be appointed to consider the possibility of the organization of a publicity bureau. This shall have for its purpose the dissemination of chemical information, and serve as a check upon the misstatements so frequently appearing in the public prints. Something of the sort is sorely needed.

We are reminded by some miscellaneous reading of newspapers and periodicals that we have done of late, and by historical data and legends that scientific misinformation will creep into places of the most acknowledged enlightenment all unawares.

"If you see it in *The Sun* it's so" is a maxim that we learned when we were young and twenty, and we have always held to it—more or less. And yet we confess to an emotional jolt or jar when, a couple of weeks ago, we learned from a news item in *The Sun* that bromine, if dropped upon the sand, will cause it to develop great heat and to harden into stone. This is as we remember it; if we err in the particulars we pray for forgiveness. A few days later *The Tribune* gave in detail the remarkable discovery of a Mr. Morrison, of whom it is said that he is not a professional chemist, but that he maintained his own laboratory. It was a method of beating the oil companies by avoiding the use of gasoline in automobiles. Comparison is made between Mr. Morrison's invention and that of a Mr. Enright who, it seems, has developed a "green powder" that he almost—but not quite—sold to Henry Ford, and which has already developed a flurry on the curb market. "Mr. Enright," says *The Tribune*, "claims that he decomposes water, thereby obtaining his hydrogen—a process which has never yet been demonstrated." We thought we had come across some hydrogen in our day that had been obtained by the decomposition of water,

but now, as we enter into *The Tribune's* habit of thought, we are disposed to say that we must have been mistaken, and that the hydrogen probably came from the air. Or maybe from *The Sun's* bromine, or from its rocky sand. It is easy to get mixed up over these things. "Mr. Morrison," continues the newspaper, "generates his hydrogen by the union of water with a chemical," and we are informed that his theory is simple in the extreme. "The chemicals he uses are metallic sodium and ammonia. . . . When water comes in contact with the sodium, the chemical action, as explained by a chemist, takes place as follows:



We wonder who the chemist was who "explained" it? The valuable by-product was also noted, and the whole story fills us with desire to load up our old 1912 model with sodium, ammonia and water and take a lovely springtime drive up in Westchester County around the Bloomingdale asylum, and then come back and get rich selling nitrate of soda to the fertilizer people.

The *New York Times* is usually very careful of its news, and we have great confidence in whatever it says, but we are in the throes and wallows of doubt about the following, which appeared on May 25. Under the scare head that "Rockefeller Riches Back Air Nitrate Co." it states with great gusto that liquid air is to be produced in this country. The new company has eight plants in operation and seven in process of construction to make liquid oxygen. "Plants for the extraction of nitrogen from the air for the conversion of nitrogen into cyanamid and the production of nitrates by the Claude process may be begun at any time. . . . The extraction of nitrogen requires much more power than the extraction of oxygen." There we have it! They "extract" liquid oxygen from the air by low power and they "extract" liquid nitrogen from the air by high power. Why didn't they ask somebody about this? The change of a few words would have made the article readable, reasonable and true. As it stands it misleads the layman and makes the chemist sigh.

In the June number of *The American Magazine* there is an interesting article on "Ambitious Business Men Rising to a New Opportunity," which treats in part of the same subject. It is a good article, and we are glad to see the kind printed in the magazines, except for the bulls that will creep in when any one of thousands of men right here in New York would have gladly eliminated them by a single reading. For instance, it is indicated that nitrogen may be "fixed" by making liquid air. And again: "The process consists in reducing the air to a very low temperature by means of powerful compressors." Of course, the compressors were there and the author saw them, but just a little advice would have made it right instead of wrong. This reminds us of the inventor who had a plan to establish a very high temperature by the rapid compression of hydrogen and then maintaining the heat by letting the hot gas escape.

Another hydrogen expert appeared before the managers of the Chemical Exhibition last fall with a master thought. "It takes 80,000 cu. ft. of hydrogen to lift a balloon," said this man of vision. "Very well, I plan to compress hydrogen in units of 80,000 cu. ft. into small cylinders. Then fasten as many of these cylinders as you please to an airy-o-plane, and up she'll go." Still another appealed to a patent lawyer with a plan to make ammonia from gasoline. "But where's your nitro-

gen?" asked the lawyer, as he proceeded to write down C_nH_{n+2} . "Hell!" exclaimed the pious prophet of nature. "There's nitrogen to spare. Look here," and he proceeded to rewrite C_nH_{n+2} . Lots of nitrogen!

But, alas! it is not alone among tufted inventors and astute and lively reporters and experts on popular heart throbs that the things go wrong. When Willard Gibbs was professor at Yale he read his original paper on the phase rule before the Connecticut Academy of Science. It was, as we recall it, sometime in the middle seventies. Nobody seemed to pay any attention to it. Old Gibbs was a theorist, anyway. Then, about twenty years afterwards, the elder Ostwald, following the footprints of Gibbs, discovered the paper among the forgotten archives of the academy, which he translated into German and published with all credit to the author. Thus we have learned of the phase rule first from the German translation. Of what nature was the long slumber of the learned Connecticut Academy? The Yale professors of chemistry and physics must also have been sleeping soundly to leave this great treasure at hand all unnoticed.

But we do not have to abide within the domain of science to find more examples. A man named Jarves had lived long in Italy. He collected paintings of the primitives, and brought them back to America. In time he became financially embarrassed. There were no museums of importance here at the time, so he went to Harvard and offered his priceless collection as a pledge to any well-wisher of the university who would loan the sum needed, the pictures to become the property of the corporation in case he should default in payment. Harvard was not interested. Mr. Jarves was not a Boston man. Then he took the pictures to Yale, and finally he secured \$20,000 from a Yale benefactor against his note and collateral. When the debt matured he could not meet it, and he died in an agony of disappointment. Over his grave arose the humor of the situation. Yale was stung for fair! Twenty thousand dollars that probably would have come in to Old Eli, now wasted in paying that dead man's debts, and what had they to show for it? A lot of junk! Those skinny old saints and angels were the laughing stock of college life. There were cat-calls and moans for those bunches of bones. Finally, after many years, a man came along who told the learned authorities about those pictures, of their almost incalculable value, how no more could be brought out of Italy for love or money, and of a bid of \$20,000, still good, for the least important piece of the whole collection. The \$20,000 bid seemed to wake the authorities up. Now if you go to New Haven you must not fail to see the Jarves collection of Italian primitives. They are wonderful, and they are kept in a fireproof gallery specially built for them. Yale is justly proud of her great treasure. But where were the learned professors of mediaeval history and art all those years?

No, it is too bad, really too bad that there is so little contagious curiosity around. That *American Magazine* article is good and useful; it tells many things that it is well for industrial chemistry to have told. It is excellent, too, that *The Tribune* and *The Sun* print articles about chemistry, even if they do contain statements that startle. What we deplore is that the truth seems to have so little standing in the editorial mind in regard to things scientific. Indeed, facts seem to be out of favor. On the other hand, things that are beyond the range of possibility appear on front pages, adorned with scare heads. We do not pretend to say that this is so for the same reason that little children prefer to hear fairy stories rather than authentic history. The whole thing baffles us. We observe, how-

ever, an utter lack of curiosity on the part of those who issue the public prints to find out whether a scientific statement is right or not. It would be easy enough to find out. The editors of technical journals are always willing to be interviewed by sincere reporters, and so are the many professors and instructors of science. The Chemists' Club is surely not discouraging to scientific inquiry, and if anybody were to go there burdened with an elementary question in chemistry he would not be turned away. That is what the library is there for. There are plenty of opportunities for writers on New York publications to get their questions answered willingly. The trouble is they do not ask.

PETER TEN BROECK.

Chemistry and Daily Papers

To the Editor of Metallurgical & Chemical Engineering

Sir:—In the New York *Tribune* of Sunday, May 14, 1916, in which the Preparedness Parade held in New York City the day before was appropriately and extensively treated, there appeared as a leading editorial "Water Power and Preparedness," based upon the Washington, D. C., meeting of the American Electrochemical Society and its symposium on Niagara water power. In the course of this editorial occurred the following statements:

"It is perhaps not unnatural that the public is ignorant of its interest in this vital question. Engineers and technical men are themselves largely responsible for the popular apathy since they have left the matter in the hands of ignorant legislators and met the restriction of power development with what could at best be described as passive resistance. . . . Yet our only hope at present is in the scientific and technical men. They have been too easy-going and have not taken sufficient pains to explain their aims and purposes to the public. It is only by doing so that they can hope to bring pressure to bear on legislators. . . . In the recent meeting of the American Electrochemical Society there were signs of a clearer realization among technical men of their public responsibility in this matter. This all to the good, for it is only through their efforts that the public can be made to understand what they have a right to demand of their legislators."

Speaking from my own personal experience I am convinced that the editors of our own daily papers are themselves in good measure responsible for the conditions referred to in the above quotations. In February, 1911, acting as Secretary of the Eighth International Congress of Applied Chemistry, to be held in Washington and New York in September, 1912, I sent to the editors of the daily papers in New York, Philadelphia, Boston, Baltimore, Washington, D. C., Chicago, Pittsburgh, St. Paul, Minneapolis, Omaha, Kansas City, Denver, San Francisco, and other cities, a short history of the seven preceding Congresses and statistical information as to their labors, also copies of our first pamphlet describing our aims and purposes and organization; in all 390 dailies all over the country were so approached. So far as I was able to learn, only two papers in two different states, both west of the Mississippi, took any notice whatever.

In June of that year I followed the February material up with more material and gave a short abstract of what we had accomplished and of what we hoped still to do, and sent that also to these same papers and about 150 boards of trade and chambers of commerce, and 8,000 manufacturers all over the country. At intervals thereafter I reported progress to the daily press in about the same way. Up to the summer of 1912, not one single New York daily took the slightest note of the matter sent to them. During that summer one daily did say something about the Congress, but only because we made very great personal effort to arouse the interest of that paper.

During the summer of 1912 one other New York daily did give about a quarter column to the Congress, printing a clipping out of the Consular Reports; but this clipped matter reached the Consular Reports because our Consul at St. Petersburg, Russia, with whom I had been in very active correspondence about the Congress, sent this matter to Washington as a news item. I had sent precisely that same information to that same New York editor eight months before, but it had no value to his paper until he found it in the Consular Reports, even though it was then more than eight months old.

When the Congress program was ready, I sent copies to every New York paper and as I recall it only two took any notice during its sessions of what the Congress was trying to do. Toward the end of its session they became a little more interested; but only in a lukewarm way. During this Congress two public lectures were given, whose combined attendance was something over 3000; at the first of these lectures an exhaustive and illustrative treatment was given of the Norwegian process of making nitric acid from air; at the second lecture an experimental demonstration of the synthetic production of ammonia was given; these two things are probably as great achievements as have been accomplished within the last generation, yet the New York dailies took no note of it whatever, and it was not until a clever Chicago reporter lampooned it that the press took notice of it; the only way that synthetic nitric and synthetic ammonia could break into our daily papers was through such an extravagant statement, as, for instance, "Chemists make Eggs out of Air"; it certainly is a very long way from synthetic ammonia and synthetic nitric to synthetic eggs.

This Congress was by no means a negligible affair; twenty-eight countries took part in it; eighteen different countries had organizations for preparation for the Congress, and these foreign organizations comprised 573 individuals and fifty-five societies. The American organization numbered upwards of 1500 technical and scientific men whose purpose was to promote the interests of the Congress. We distributed our news service to 438 trade, technical and scientific publications the world over, and this exclusive of our news service to the daily press; altogether we sent out over 300,000 pieces of printed matter informing the public what our aims and purposes were; 151 public meetings were held in New York City during the week this Congress was in session.

At the New Orleans meeting of the American Chemical Society, in March and April, 1915, that is, after we had had eight months of the great war, there were nineteen short papers presented, each of them wholly in non-technical language, on what the American chemists had done for nineteen American industries; advance proofs of each of these papers together with a short résumé of each of them, and all printed, were sent to the editors of about thirty prominent dailies inclusive of New York dailies; outside of New Orleans I could find but one daily that took any notice whatever of the matter and that was done by the simple process of "lifting" one of the articles as an editorial without giving any credit whatever to the American Chemical Society.

The first point of entry for publicity *must* be by way of the editors of our dailies; if they block the way nothing can be done. We must first educate our editors as to what the country should know, and then induce the editors to educate the public. The editors know better than any one else the mechanism for educating the public; if the editors will receive technical matter in a welcoming way, it is absolutely certain that the technical men will state their case in the lan-

guage and form which the editors consider best fitted for instructing the public. I say this, even though it has happened to me that after spending nine hours with an efficient editorial writer of a large New York daily, in explaining technical matters to him and in going over his manuscript and his copy and had boiled down a very technical story into fewer than 1500 words, our combined effort was crowded out by the editor-in-chief because he needed the space for something else. However, I am not discouraged; I still believe that our editors can be educated up to the point of wanting technical matters, and if the editors will come only one-third the way, the technical men will gladly go the rest of the distance.

BERNHARD C. HESSE.

New York City.

The Nitrogen Industry

To the Editor of Metallurgical & Chemical Engineering

SIR:—In a number of magazines and papers in this country there have appeared in the last few weeks a series of articles dealing with the nitrogen industry.

Most of these articles deal exclusively with the three different processes for the fixation of atmospheric nitrogen, namely, the carbide-cyanamid process, the arc process, and the Haber process, leaving out all the other industries manufacturing nitrogen or ammonia, for instance, the by-product coke ovens. This industry has made enormous progress in the United States in the last few years and produces to-day about 50,000 tons of ammonia per year in form of sulphate of ammonia or ammonia liquor, while the production in 1905 did not exceed 16,000 tons of ammonia. The United States cokes nearly as much as England and Germany combined and if all coke ovens had been by-product coke ovens the total output of nitrogen would have been nearly 200,000 tons.

Regarding the fixation of the atmospheric nitrogen, we will find statements which may give the impression that the carbide-cyanamid production is the only nitrogen industry fitted for this country, and that neither the arc process nor the Haber process can compete with the cyanamid process for the manufacture of nitric acid and its derivatives or of ammonia. The cyanamid process requires about 2.5 hp.-year for 2000 lb. nitrogen. The arc process in its present stage requires about 10 hp.-years per 2000 lb. nitrogen, or four times as much as the cyanamid process. The Haber process requires less than 0.2 hp.-year per 2000 lb. nitrogen, or about one-twelfth of the power required by the carbide-cyanamid process.

The cyanamid process and still more the arc process depend thus upon cheap power, while the power used by the Haber process is negligible, and without any influence on the cost of the final product.

Taking the arc process and the carbide-cyanamid process, the former uses, besides power, only air and water as raw materials, while the latter uses, besides power, lime, coke, coal, electrodes, nitrogen, etc., some of these raw materials in considerable quantities. By making, for instance, nitric acid by the cyanamid process, we have to produce carbide, cyanamid and ammonia, and from this, by oxidation, weak nitric acid, which has to be concentrated by means of heat supplied by coal, consequently a great number of operations which use a lot of workmen and cost money. By the arc process, we obtain at once weak nitric acid, which, by means of the heat developed by the furnace, which thus does not cost anything, can be concentrated to 98 per cent acid.

The arc process requires very few workmen and is comparatively a very much simpler process than the

carbide-cyanamid process. In fact, the main cost is the power. Detailed estimates on both processes show that the nitric acid, with steam power produced from coal at \$1.00 per ton, can be produced just as cheap by the arc process as from cyanamid, and there is, no doubt, in the United States an enormous amount of water power that can be developed at such cost as to deliver the power considerably than a steam plant located at the coal mines.

Supposing a nitric acid factory is erected for the purpose of delivering acid for war purposes; such a factory would in peace time deliver cyanamid, if the cyanamid process is applied, and nitrate of lime, or better, nitrate of ammonia if the arc process is applied. Nitrate of ammonia is an excellent fertilizer material that, on account of its concentrated form (42 per cent ammonia), can stand a heavy freight. The arc process utilizes at the present in Norway about 360,000 continuous horsepower, corresponding to a production of about 36,000 tons of nitrogen. Smaller factories using the arc process are also under construction in Spain, France and Germany. A big project for utilizing more than 100,000 electric horsepower produced by steam is under way in Germany and there is also a scheme using water power under way in Russia.

Of course, each of these schemes has been thoroughly examined as to their economical outlook in competition with the other processes, and there is no reason whatever why the arc process should not be applied in this country for the production of nitric acid in competition with the cyanamid or any other process.

The main reason why Germany has increased the production of cyanamid to such an enormous extent during the war is due only to the fact that she was obliged to do so. When the supply from Chile was cut off, Germany faced a serious situation and had to secure nitrogen from all possible sources in the most limited time. The cyanamid process was chosen for the supply of nitrogen that could not be covered immediately by the Haber process, because it does not require more than one-fourth of the power of the arc process and thus can be constructed in shorter time and while water powers are very scarce in Germany. The demand of the German cyanamid group for the establishment of a nitrogen monopoly in Germany as a condition for the extension of their plants seems to be due to the circumstances that the cyanamid group wishes to secure their industry for a period after the war.

Turning to the Haber process, we will find that this process does not depend upon power at all, and the belief that the Haber process uses fully half the power required by a well-constructed carbide-cyanamid plant is not correct. The sole product by the Haber process is ammonia, from which nitric acid, all kinds of nitrates and sulphate of ammonia can be produced just as well as ammonia from cyanamid. The number of workmen used by the Haber process for producing ammonia is considerably less than used by the cyanamid process. Skilled labor is required to about the same extent as by the cyanamid process.

There is no reason why the Haber process should not be operated in this country just as economically as in Germany. Dr. Bernthsen, in his lecture on the Haber process at the Eighth International Congress of Applied Chemistry in September, 1912, made this statement: "There is every reason to assume that this industry will find a fruitful field of employment in America, where the demand for nitrogen-manures will soon be greater than hitherto."

Since that time, the Badische has erected factories in Germany, using the Haber process, with a production

of more than 75,000 tons of ammonia, while in 1912 the production was only 7500 tons of ammonia.

The cost of production of ammonia with the Haber process is able to compete with any other processes. On account of the war, the Badische has not made any attempt to introduce the Haber process abroad.

To sum up the above, there is no reason whatever why all of the three processes for the fixation of atmospheric nitrogen should not be operated in this country, as they have been in Europe, and it requires a thorough investigation of each single case in order to decide which process should be applied. To believe that only one of the processes is suitable for the United States is to overlook many considerations and to underestimate the resources of this country.

EYSTEIN BERG.

New York City.

The Newlands Bill and National Research

BY WILLIS R. WHITNEY

Some two hundred representative men of science in the United States have been requested to give their opinions upon the Newlands Bill as an initial step in the national organization of research. Of over sixty replies already received only seven have been otherwise than heartily favorable.

The objections raised in these seven letters fall into three classes, in order of emphasis as follows:

1. The grants will in many cases fall into the hands of untrained men and institutions, and not be employed to good advantage.

2. Small grants distributed to the separate colleges will not be nearly so effective as the total sum devoted to one central organization.

3. The term "Engineering and Mechanics Arts" neglects Chemistry.

To the last criticism it may be replied that however little chemistry may be mentioned it will still get its due, because it is an absolutely essential factor in almost all problems. Few indeed are the researches which do not involve chemical investigation at some point.

In regard to the other two objections, have not certain extremely important factors in the situation been overlooked? If the research accomplishment of the future is going to be limited to the circles of influence of just those men, universities and laboratories which have so far shown themselves relatively efficient, is not the growth of new knowledge going to be about as slow as during the last decade? Have we any reason for believing that the potential talent of the country is so segregated either geographically, or by financial resource, that all that is good, or even a relatively large proportion of it, may fall under the influence of these few selected men and institutions? The potential research man is not a distinct type. He wears no mark, for himself or others to recognize, and if removed some hundreds of miles from any example of research, is he not pretty likely to follow a nearer example, and be lost to this field which needs him so much? If America is to take her proper place in the world she must produce advanced workers at a much faster rate than ever before.

To do this she must draw into the ranks of research more of the suitable minds which we have no reason to doubt exist among our people.

Suppose a certain land grant college has never produced research. Is the grant of a sum for the purpose going to make it less likely to produce? Such a college is an undeveloped field. Is it not possible that it can be made productive, and is it not good policy to try? The large and thriving institutions hold no complete monopoly of talent nor of right to assistance. Why not

encourage the little fellows to realize their possibilities?

Our necessity is not alone for more men to perform research. It is equally for more men who know the significance and aspect of research, and so understand its possibilities. In a democracy, advance in any direction whatever, is only possible through the conviction of the average man that it is desirable. Research in its national aspect can never be served by constituting it an aristocracy of men or of institutions. It must rather become the familiar tool whose use all may know and welcome, even though an understanding of its inner mechanism may require an expert.

I will let some of those who favor the bill as a constructive measure answer the objections in their own words.

Prof. Edward W. Morley, Western Reserve University: "I feel about the Newlands Bill, as I judge you also feel, that it is at best a small beginning at a complicated and difficult matter; that it at least is a beginning; and that it should therefore receive the cordial support of all of us who know how immensely important scientific research is to the welfare of the country."

Prof. Ira Remsen, Johns Hopkins University: "Your circular letter of April 29 with the enclosure was received a few days ago. A careful reading of both leads me to the conclusion that the Newlands Bill is for the interest of science and therefore in the interest of the country. It has my hearty approval."

Prof. William T. Sedgwick, Mass. Institute of Technology: "I heartily concur in your scheme for establishing Engineering Experiment Stations in the colleges, and sincerely believe that this would be an admirable way to set going a large amount of useful research work in this country."

William Brady, Chief Chemist, Illinois Steel Company: "I have felt for a long time that the Government should support industrial research. I saw no real practical way of doing it. A Bureau at Washington did not appeal to me as just the right procedure. I do feel, however, that the work should be supported by our National Government and be under Government control."

"The proposed bill is more in accord with my ideas on the subject than any scheme that has yet come to my notice."

W. C. Geer, of the B. F. Goodrich Company, Akron, Ohio: "I am a great believer in research and believe that the possibilities of this country are great if properly handled, and I fully agree with you that the method you suggest for promoting research in this country is far preferable to that of a large central research organization. Such a plan will utilize at once the equipment available. It would attract in the simplest way men who otherwise never spend time in investigation."

Prof. T. W. Richards, of Wolcott Gibbs Memorial Laboratory, Harvard University: "It seems to me that the Newlands Bill will undoubtedly help in drawing attention to the importance of research, and in helping also to discover adequate men."

O. H. Tittman, Chief of U. S. Coast and Geodetic Survey: "One feature of the bill commends itself especially to me, and that is the creation of many centers of interest and usefulness rather than that of a single centralized agency for experimental research. The necessary coordination can be provided by a central administrative office."

Prof. Chas. E. Locke, of Massachusetts Institute of Technology: "In the mining department, I believe that we are all in favor of the bill, our idea being that an allowance for research, though small in amount, is better than nothing. We have always carried on more or less research in the department, and for years Professor

Richards had private assistants who have carried out the experiments which have resulted in Professor Richards' discoveries and improvements, especially along ore-dressing lines. In addition to pure theoretical research, these assistants have done a great deal in solving commercial problems which are coming to us at frequent intervals. Fortunately Professor Richards has felt able to carry the financial burden of this research work, but all of us are not in that position and therefore appreciating the value of such work, would welcome any aid financially toward keeping it up."

Dr. E. P. Hyde, of Nela Research Laboratory: "It has been my judgment for a number of years that every effort should be made to develop in the United States research in both pure and industrial science and to foster a closer relationship between these and engineering, and I have felt that the present conflict in Europe has at the same time emphasized the importance of this work, and laid upon the United States the responsibility of assuming the leadership in it."

Dr. Louis Bell, of Boston, Mass.: "I heartily approve of the project as being about the most suitable thing in the way of aid to ultimate industrial development that our country has yet done. The annual appropriations of various technical departments of the Government are large, but I do not think they produce results entirely commensurate with the expenditure because they are too closely centralized and cannot make available the wide variety of talents which can be reached by the Newlands Bill."

Dr. P. G. Nutting, President of the Association for the Advancement of Applied Optics: "The Newlands Bill has my hearty endorsement for a number of reasons.

1. It is, in my opinion, the most *rational* plan for stimulating and promoting research yet proposed.

2. It is likely to produce greater *practical* results than any other scheme yet advised.

3. It is a logical extension of the government-aided agricultural research, already long past the trial stage and of proven worth.

4. It will serve the *varied interests* of the different sections of the country far better than a single central laboratory.

5. It is likely to draw fertile-minded *investigators* in far greater numbers and in far greater variety of race and training than a single federal institution. This I consider the strongest argument in its favor.

6. The contemplated distribution of laboratories will provide more *intimate relations* between research and the interests most likely to profit by it. This will lead to a better choice of research problems and greater activity in investigating them."

Prof. Henry S. Jacoby, of Cornell University: "The results which have been secured by the Engineering Experiment Station at the University of Illinois, supported by the State, show how fruitful may be such a station associated with a university.

"It is hardly possible to overestimate the aid rendered by that station in the development of a rational basis for the design of reinforced concrete since this new material of construction was introduced in the country. This is but one of many subjects investigated by that station, whose good work is recognized by engineers in other countries, as well as in our own."

C. F. Burgess, Chemical Engineer, Madison, Wis.: "In considering my past experience as a teacher, I can say that there is no doubt that research work can be greatly stimulated by having available certain funds which are to be devoted exclusively to such work.

"I applied a number of years ago for a grant from the Carnegie Institution and \$2,500 a year was made avail-

able for research on electrolytic iron and iron alloys. I can show that through this expenditure, over a period of five years, not only were results of practical importance secured, but what is even more important, a number of men were developed as investigators. If it had not been for this fund it is possible that Mr. James Aston who is now carrying on important research work for the Bureau of Mines, might still be engaged in foundry practice.

"Among other men who received part of their training and encouragement in research work through this fund are Dr. O. P. Watts, J. H. Thickens, and O. L. Kowalke, all of whom are now high grade research men.

"There are a great many college men now engaged in technical and purely routine work in industrial lines who would be attracted back to the universities for research work if such funds were available, men who cannot afford to give up their income completely and men who can quickly develop into competent investigators."

Prof. J. H. Long, Northwestern University Medical School: "I have for a long time felt that we need in this country some more tangible stimulus to beginners in research work than we at present possess; the plan of the Newlands Bill may help in the solution of the difficulty."

Program of Cleveland Meeting, American Institute of Chemical Engineers

The eighth semi-annual meeting of the American Institute of Chemical Engineers will be held at Cleveland, Ohio, from Wednesday, June 14, to Saturday, June 17, 1916. Headquarters will be at the Hotel Statler. Meetings will be held at the Hotel Statler and at the University Club, including a joint meeting with the Cleveland section of the American Chemical Society.

On Wednesday morning a meeting will be held at Hotel Statler with the following program:

Address of welcome, by Ralph L. Fuller, president of Cleveland Chamber of Commerce.

The Production of the Rarer Metals. By Joseph W. Richards.

The Utilization of American Clays. By Arthur C. Watts.

The Effect of Storage on Mixed Paints. By E. E. Ware and R. E. Christman.

At the Wednesday evening meeting at the University Club, the following papers will be read:

Recent Developments in the Production of Nitrocellulose. By Dr. Edward C. Worden.

Nitric Acid Sulfonation, a Serious Production Menace. By James R. Withrow.

On Thursday afternoon there will be a lecture on "Sound" by Dr. Daton C. Miller, of the Case School of Applied Science, at the Students' Club of Case School.

On Friday afternoon the following papers will be read:

The Cleveland Sewage Disposal Plant. By R. Winslow Pratt.

The Purification of Sewage by Aeration in the Presence of Activated Sludge. II. By Edward Bartow.

On Friday evening a joint meeting will be held with the Cleveland Section of the American Chemical Society at which the following papers will be read:

Water Powers of the United States. By Herman Stabler, U. S. Geological Survey.

Acid-Resisting Alloys. By W. C. Carnell.

Excursions will be made on Wednesday afternoon to the Central Furnaces, the Semet-Solvay by-product coke-oven plant of the Cleveland Furnace Company, and to the American Steel & Wire Company. On Thursday morning the ore docks of the Pennsylvania Railway

Company, the Cleveland filtration plant, and the works of the National Carbon Company, will be visited. On Friday morning a visit will be made to the National Lamp Works of the General Electric Company, and on Saturday morning to the works of the Goodrich Rubber Company.

The social features include a smoker and entertainment on Wednesday evening after the technical session; a complimentary luncheon on Thursday noon, with address of welcome by Charles S. Howe, president of Case School of Applied Science; a subscription dinner on Thursday evening at Hotel Statler; and a complimentary luncheon by the Grasselli Chemical Company at the Country Club, Friday noon.

Dr. George D. Rosengarten is president and Dr. John C. Olsen, Cooper Union, New York City, is secretary of the Institute.

The Western Metallurgical Field Zinc and Copper Production in 1915

Official figures on the production of spelter and copper in the United States for 1915 have been published by the U. S. Geological Survey. The report on spelter contains a graphic representation of the average prices per pound at St. Louis and London, the average base price of 60 per cent zinc concentrates at Joplin, and the weekly production of zinc concentrates in the Joplin district. The price of the metal at St. Louis reached its maximum on June 12, 1915, when it averaged slightly over \$0.25. Another high point was reached on Nov. 27, at \$0.22. The high average price for Joplin concentrates was \$130 per ton on June 12. The production of primary spelter in 1915 amounted to 489,519 tons of 2000 lb., with a value of \$121,401,000 based on the average selling price. This was an increase of 39 per cent in production and 237 per cent in value as compared with 1914. Consumption of primary spelter in the United States increased 22 per cent as compared with 1914. The list of active zinc smelters in the United States shows 156,568 retorts in operation, with 49,612 to be added in 1916, which will make a total of 206,180. Ten electrolytic zinc plants are listed, indicating the remarkable impetus given to this branch of zinc metallurgy during the year. The total capacity of all spelter plants in the country is estimated at 885,000 tons annually. The output of electrolytic zinc for 1915 is given as 252 tons, but the estimate for the end of 1916 is at the rate of 60,000 tons per annum. The future of the industry indicates that this country will be producing spelter at the rate of about 900,000 tons per annum, including secondary metal, which is about three times domestic consumption. This suggests that at the close of the war some of our zinc plants must inevitably close unless in the meantime arrangements are made to smelt practically the entire Australian production in this country. In that event smelters situated on the Atlantic seaboard with adjacent markets for acid will have an advantage over inland smelters.

The smelter production of primary copper in 1915 amounted to 1,388,000,000 lb., an increase of 21 per cent over that of 1914. The total value of the 1915 production, at an average price of 17.5 cents per pound, was \$242,900,000, compared with \$152,900,000 for 1914. The principal copper-producing states, arranged in order of production, rank as follows: Arizona, 432,467,690 lb.; Montana, 268,263,040; Michigan, 238,956,410; Utah, 175,177,695; Alaska, 70,695,286; Nevada, 67,757,322; New Mexico, 62,817,234. The total production of new refined copper in 1915 was 1,634,000,000 lb., an increase of 100,000,000 lb. over 1914. Production of secondary copper amounted to 392,274,000 lb. The total contri-

bution of the United States to the world's supply of copper in 1915 is given as 2,026,000,000 lb. The apparent consumption of new refined copper in this country in 1915 was about 1,043,000,000 lb., compared with 620,445,373 lb. in 1914.

Company Reports

The Calumet & Arizona Mining Co. produced in 1915 65,268,910 lb. copper, 1,381,078 oz. silver and 35,264 oz. gold. Income amounted to \$11,683,724, and expenditures totalled \$6,225,595, leaving a net income of \$5,458,129. Dividends amounted to \$2,006,557. An interesting part of the report refers to the leaching and electrolytic plant of the New Cornelia Copper Co. A 40-ton experimental leaching plant was operated during the year, treating 291 charges. Results on charges 91-291 were as follows:

Average head, copper.....	1.337%
Average tailing, copper.....	0.256%
Average extraction	80.600%
Average pounds per kw. hr.	0.958

On the basis of these tests an appropriation of \$4,200,000 was made for a permanent plant, which when completed will yield copper at the rate of 36,000,000 lb. per annum. The ore will be crushed to $\frac{1}{4}$ in. and leached in eleven lead-lined vats, each 88 ft. square by 15 ft. deep inside, having a capacity of 5000 tons each. Each vat will have its pumping system for circulating solution at the rate of about 8000 gal. per minute. An excavator of the Hulett type will be provided for discharging the vats after the ore is leached. The neutral solution from the leaching plant will be pumped to sulphur dioxide absorption towers for the reduction of ferric iron before electrolysis. The acid solution after electrolysis will be returned to the leaching plant. The tank house will contain 152 lead-lined electrolytic tanks about 30 ft. long, 4 ft. wide and 5 ft. deep. It is estimated that the plant will be ready for operation about July 1, 1917.

The consolidated earnings statement of the United States Smelting, Refining & Mining Co. for 1915 shows net earnings of \$6,592,324 which, with the undistributed surplus from the previous year, gives a total of \$11,107,916. Dividends were paid amounting to \$1,965,561; additional reserves for depreciation, \$888,900; undistributed surplus, \$8,253,455. Metal production was as follows: Copper, 26,923,674 lb.; lead, 87,102,179 lb.; zinc, 34,105,471 lb.; silver, 12,071,863 oz.; gold, 196,481 oz. The company's subsidiaries are: United States Smelting, owning zinc and lead mines and smelters in Utah and Kansas; Centennial-Eureka Mining Co., Utah; Mammoth Copper Mining Co., California; Gold Road Mines Co., Arizona; Needles Mining & Smelting Co., Arizona; Richmond-Eureka Mining Co., Utah; Real del Monte y Pachuca Mines in Mexico. Owing to disturbances in Mexico the latter properties were operated only from 50 per cent to 80 per cent of their capacity.

The annual report of the Consolidated Arizona Smelting Co. for 1915 shows a general improvement in the condition of the company's mines and reduction plants. A suit brought by Charles S. Hinchman to impress a lien of \$900,000 upon the company's property was decided favorably to the company in the Circuit Court of Appeals. Ore reserves in the Bluebell mine are given as 235,000 tons containing \$1.50 in gold and silver and 3.5 per cent copper; in the De Soto mine, 65,000 tons of the same gold and silver value as in the Bluebell, and with 3.75 per cent copper. The concentrating mill handled 81,544 tons of ore and old tailings and made an average recovery of 88.6 per cent of the copper, 62.5 per cent of the gold and 70.5 per cent of the silver. The grade of feed was 2.83 per cent copper, the ore aver-

ing 2.88 per cent and the tailings 2.09 per cent. Ratio of concentration, 4.1:1; grade of concentrate, 10.27 per cent copper. The cost of milling, including flotation royalty, was \$1.20 per ton, compared with \$1.82 and \$2.09 in 1914 and 1913, respectively. No flotation royalty was paid in 1913. Additions to the crushing and milling plant will be made to increase capacity from 240 tons to 500 tons per day. The smelter cost of receiving, crushing, sampling, handling, roasting and smelting to matte was \$3.34 per ton, as compared with \$5.55 in 1914. Cost of converting matte to blister copper was \$0.0046 per pound of copper converted. In 1914 this cost was \$0.0058, and in 1913, \$0.0137. The full effect of improvements and economies on the cost of producing copper will be apparent only during 1916, but with improved conditions the company expects to increase its output and decrease cost. Net profit for 1915 was \$194,943, without considering depreciation.

The earnings of the American Smelting & Refining Co. for 1915 amounted to \$16,242,420, an increase of \$5,430,505 over 1914. The following appropriations from earnings were made: For depreciation, \$1,839,686; employees' bonuses, \$445,000; pension fund, \$100,000; welfare work, \$250,000. Dividend payments amounted to \$8,002,924. The surplus was \$5,050,380. The company's properties in Mexico were, on the whole, unprofitable and unproductive. In addition to mining properties purchased during the year the company constructed a tin smelting plant at Perth Amboy, zinc smelting plants at Salt Lake City and Sand Springs, Okla., and a new copper refinery at Tacoma. The company extended its welfare work for employees; pensioned forty-eight old or disabled employees during the year, and has a pension fund of \$620,420.

The Copper Range Company, Michigan, earned a net income of \$3,564,762 in 1915, and paid dividends of \$1,182,003, leaving a balance to working capital of \$2,382,759. The total copper production was 37,035,642 lb., at an average cost of 8.06 cents per pound. The average price received was 17.4 cents. Rock stamped totalled 1,651,870 tons, containing an average of 32.5 lb. copper per ton.

The Daly-Judge Mining Co., Utah, had a profitable year, according to the annual report for 1915. The increase in profits was due to the higher price prevailing for lead and zinc as well as to increased ore production. The excess of receipts over disbursements amounted to \$238,753, and the balance carried to surplus was \$678,907. Dividend payments amounted to \$300,000. Ore production was 5809 tons of shipping ore and 63,935 tons of concentrating ore. The average grade and value per ton of ore and concentrates produced is given in the following table:

	Oz. Silver	Oz. Gold	Per Cent Lead	Per Cent Copper	Per Cent Zinc	Per Cent Iron	Sold For
Crude	30.32	0.034	17.73	1.86	10.82	7.67	\$23.93
Lead conc.	31.72	0.03	38.57	1.18	9.93	15.01	33.26
Zinc conc.	17.41	0.015	3.77	...	44.46	6.08	63.08

The constituent companies of Phelps, Dodge & Co. produced during 1915 a total of 140,478,003 lb. copper, an increase of 8,815,679 over 1914. This large production was accomplished in spite of labor strikes that closed the Detroit mines from September to the close of the year. The Nacozari plant was closed for 135 days, due to troubles in Mexico. The balance sheet shows earnings of \$10,981,512 and a surplus of \$8,337,864. Dividends totalled 20 per cent, or \$9,000,000. At the Burro Mountain property the company is erecting a large concentrating mill, one 500-ton section of which may be in operation at the present time. The milling system has been developed as the result of experimenting with over 10,000 tons of ore of various types.

The Roitsheim-Remy Continuous Zinc Distillation Process

BY M. LIEBIG

Smelter Superintendent in Godesberg

TRANSLATED BY OLIVER C. RALSTON

From *Metall und Erz*, 13, 143-156 (March 22, 1916).

At the autumn meeting of the Gesellschaft Deutscher Metallhütten und Bergleute (German Metallurgical and Mining Society) in 1913, I reviewed a series of proposed and tested processes for the improvement of the smelting of zinc in vessels heated from the outside (*Metall und Erz*, 1914, Heft 3) and mentioned the process of Roitsheim and Remy for the distillation of zinc in vertical retorts.

This interesting process has since been tested for over a year in the Hamborn zinc smelter of the Aktiengesellschaft für Zinkindustrie, formerly Wilhelm Grillo, in Oberhausen.

I am now in a position to comment further on this

and of the inventors, and thanks to their eager cooperation, it was possible to build another test furnace in 1915 which was run in large-scale production of zinc, giving every opportunity to compare the new process with the standard old practice. Fig. 1 gives an idea of this 10-muffle installation, showing one side of the furnace and the top.

The advantages of this new process over the regular process are: first, better labor conditions; second, less dependence on labor; and third, greater ease of operation.

Every zinc smelter has been concerned in recent years with the ever-increasing gravity of the labor question. It is easy to understand the attitude of the zinc furnace man who would rather enter some other industry which is technically up to date than remain in the zinc industry, which is at a standstill, as far as technical development has been and which calls for so much physical exertion. It was this problem which the inventors sought to solve. They accepted the standpoint that the reduction of zinc oxide has been successful only in retorts heated from the outside. They merely sought by changing the arrangement of the apparatus to do away with the excessive amount of heavy manual labor.

The inventors have succeeded. By the use of suitable apparatus they have not only reduced the manual labor, but have reduced the number of laborers necessary in the zinc melter by 40 per cent. Further we find that a like diminution of the work in the muffle factory is a direct result of this invention. Not only should the news that only 60 per cent of the former labor force will be needed bring joy to the hearts of the smelter men, but also the fact that unskilled labor is all that is required for most of the work. The work is easy to learn, does not tax the strength, and takes on more

the character of watching machinery. The discharging and loading periods which formerly subjected the laborers to intense heat were also done away with and now most of this heat is conserved. Besides the solution of the vexing labor problem it has also been found that the work can be much better and is more easily carried out. It is found that the operation costs, outside of the labor, are also much lower, thanks to the configuration of the retorts. The question of discharging and loading machines has been much in the foreground, of late, and the presses for the present type of condensers are very complicated compared to the simple presses for making the muffles. The upright retorts have solved both problems. Roitsheim and Remy obtain continuous reduction by feeding preheated ore charge into the top of the retort and discharging a dezinced residue mechanically from the bottom of the retort in a cool condition. The retort is open at top and bottom, but sealed from the atmosphere above by the fresh charge and below by the "ashes." The condenser is perpendicular to the muffle and is in a suitable heated niche.

This new apparatus is so simple that the use of un-



ROITSHEIM-REMY CONTINUOUS ZINC FURNACE

invention and its practical applicability, as well as to call attention to the fact that it promises to revolutionize zinc smelting.

The inventors carried out their first tests in Langerwehe (Rheinland), in a test furnace containing six vertical retorts and demonstrated the possibility of smelting zinc by this process. On the strength of these tests an improved test plant was installed in the Hamborn smelter at Oberhausen in 1912. This furnace was built with twelve muffles, each capable of producing 25 kg. (55 lb.) of zinc per 24 hours. The residues were very low in zinc and even ores which slagged easily yielded up their zinc content without trouble. This furnace improved on the work of the Langerwehe furnace and yielded satisfactory zinc.

On that account I was able to state at the above-mentioned meeting in Berlin on Nov. 23, 1913, that I regarded the question of distillation of zinc ores in vertical retorts as solved.

The world-stirring events of the following year, which called all forces to the defence of the Fatherland, promised to hinder this work, but thanks to the fearless faith of the Aktiengesellschaft für Zinkindustrie,

skilled labor is allowable. It has been patented by the inventors in most of the important countries. Above, the muffle has a continuation for receiving the ore charge and for preheating it. Below the muffle rests on a cast-iron cooling chamber in which the extracted residues are cooled to the point where no more fumes are evolved before they are discharged by a mechanically driven discharge. In a niche cut in the wall and connected to the muffle through a hole at the proper height is the condenser, which is heated to the proper temperature for condensation of good zinc. This clay condenser is shaped like the old muffles of the three-tier Rhenish zinc furnace. It can be made in the old muffle presses so that these old presses need not be discarded in adopting the new process. So the inventors have found a simple solution of the problem of disposing of the zinc vapor. In the front end of the condenser is set the tube which leads into the prolong which catches the zinc dust. The prolong is divided by a partition so that the gases are discharged near the furnace into an opening which leads to the stack. At this opening the gases are ignited and the color of this carbon monoxide flame serves, as of old, to indicate whether there is any uncondensed zinc present, and is used as a control on the operations of the furnace.

The heating of the muffles takes place in a combustion space which is divided in the middle by a checker-work wall, and usually regenerative gas firing, like that in the best modern ovens, is used. The test furnace was built one-fourth of the proposed full size. The full-size furnace will have forty retorts, twenty on each side of the middle wall. The comparatively small combustion space, the position of the burners and the communication openings in the central wall allow of an easy regulation of the performance of the furnace, and by the use of slides actuated from the outside the supply of gases can be regulated for each muffle.

The reduction takes place quickly and quietly. The whole performance of the furnace is dependent on the muffles being kept filled with ore, and their upward extensions can easily be tended by one man. An electrically driven discharge, which is set in motion by the laborer on top of the furnace, removes a certain portion of the charge from time to time at the bottom, and with the removal of this residue the contents of the muffle must sink. In case it does not sink down the workman on top loosens it with an iron rod. This is all the manual labor which is connected with the reduction. Hence the activity of the furnace man is restricted largely to the superintendence of the machinery.

The tapping of the zinc, which is necessary only once in twenty-four hours, is easily done on account of the position of the tap hole, and the zinc runs into a portable pot. This is fairly free of lead, and the use of a mixing kettle is not necessary, as the steady reduction temperature yields a zinc which does not require further refining.

The following are examples:

Ore,	Zinc,	Zinc Dross,	Zinc,
Per Cent	Per Cent	Per Cent	Per Cent
50.46 Zn	98.87 Zn	72.87 Zn	99.02 Zn
3.76 Pb	1.24 Pb	6.62 Pb	0.860 Pb
5.90 Fe	0.014 Fe	1.46 Fe	0.033 Fe
0.61 Cu	0.004 Cu	0.49 Cu	0.000 Cu
	0.077 Cd	0.42 Cd	0.042 Cd

The tapping of the zinc is best done by two special laborers, and is easily and simply done, because there is only one row of retorts on each side and they are all at the same height. On account of the regularity of the process the condensers can be emptied at a certain time every day and two men can serve three furnaces. They first take off the prolong, collect the zinc dust, and then tap the zinc in the condenser by opening the tap

hole beneath the tube for attachment of the prolong. In order to remove any slag or dross from the muffle, the tube is removed to allow entrance of the proper tool. The tube is then replaced, luted, and the prolong stuck on again. As two men serve three furnaces, or 120 retorts, their work is not excessive. They find ample time to scrape out any condensers which are filling up with accretions. During the test run it was found that hand-made condensers lasted forty-five to fifty days. If machine pressed condensers had been used they would probably have lasted much longer. With 120 condensers and a life of forty-five days only three or four of them would have to be replaced each day in the three furnaces, work occupying only three-quarters of an hour.

The extraction is better by this process than by the old one. In the old one the operations were interrupted to allow emptying the retorts and loading them with fresh charge, and hence subjected to heavier strains than in the new process. The constant temperature to which the new retorts are subjected during their whole life contributes materially to their life. The continuous charging causes far smaller losses and the uninterrupted distillation tends to form much less dross, accretions and zinc dust, and hence less zinc has to be re-distilled. Further, by slowing down the rate of discharge it is possible to keep the ore in the heated zone longer and obtain lower grade tailings. In the test runs it was the rule to obtain 3 or 4 per cent Zn in the residue, although as low as 1 per cent was not uncommon, which naturally reduced the losses. Further, the residues not being discharged until they are cooled, there is not the old loss of zinc vapor. All these circumstances tend toward higher extraction and more or less toward a higher grade product. If the residue is assumed to contain on an average 3 to 4 per cent of zinc, the capacity of muffles for a charge of 47-50 per cent Zn content can easily be 45 kg. (99 lb.) of zinc, and with the addition of some zinc dross the capacity could be raised to 50-55 kg. (110-121 lb.). When smelting zinc oxide or only zinc dross, a capacity of 65-70 kg. is easily possible (143-154 lb.). Hence a forty-muffle furnace will smelt at least 1.8 metric tons (two short tons) of zinc daily.

The life of the retorts in the test plant was seventy to 80 days for hand-made muffles made of ordinary muffle clay. It is safe to assume that the machine-pressed muffles ought to last ninety days, and their shape is such that it does not require a complicated press. This makes it necessary to replace only five or six muffles per day in a single installation of twelve furnaces (480 retorts). Some manual labor would be involved in loosening and removing the old retorts and introducing new ones, but since the individual control of the muffles makes it possible to replace muffles without interfering with the operation of the furnace, the furnace men need not do this work, and special men can be detailed to do nothing but the replacing of muffles. An electrically driven overhead crane is necessary for carrying on this replacing operation. The replacing of five or six muffles every day can be done by seven laborers, outside of the crane runner, in about six hours. Only about half of the time of the crane is required, and the rest of the time can be occupied with other duties, such as hauling ore. It would also seem that with experience the age of retorts and condensers could be lengthened. Slagging of the muffles, by the very nature of the process, is rendered less likely and breaking of both muffles and condensers by temperature changes is also eliminated.

The removal of the residue takes place by a mechanical discharge. Each retort is provided with one. Each is set in motion by levers which extend up to the top

of the furnace, and is actually in motion only a few minutes each hour. The material discharged is usually fine grained and cooled. In the test plant, these zinc ashes discharge into tram cars in the tunnel underneath, but in larger installations the use of a conveyor belt would be better, or the material could fall into a sluice. The concentration of zinc in the ashes by gravity or other methods is easier and cheaper in this process, because crushing is not necessary, as a rule. The saving of the excess coal from these residues amounts to as much as 45 per cent of the total coal used for reduction. The consumption of cooling water is quite low if it is cooled and reused, so that only evaporation and leaks have to be made up. The mechanical discharge and ash coolers in the test work showed no visible wear after one year's work, so that they could be expected to last for several years.

Repairs to the remainder of the furnace are very small. An arch is not used. The walls of the condenser niches are strong and subjected to no abrasion. The gas and air channels are under the condenser niches and parallel to the row of muffles. Hence stoppages due to slagging or crumbling, both in these channels and in the holes through the central dividing wall, are very unlikely. The side walls form a strong block of masonry, which is heated on only one side and only the central dividing wall is subjected to heat from both sides. Complete renewal of the furnace work is easy of accomplishment, and an interruption of the work of only fourteen days results, including time to cool down and fire up again. The individual gas burners allow cutting off the supply to a single compartment long enough to make minor repairs and thus increase the length of life of the furnace setting. On account of the fact that the regenerators need to be overhauled every three years, greater improvement along this line is not necessary.

The spacing of the furnaces is also materially changed. In the old practice, with much radiant heat, it was necessary to leave a great deal of space between the furnaces, but with the new furnaces this working space between the furnaces is materially reduced. The space between the center lines of two adjoining furnaces is 11.4 meters (37 ft.), so that in a battery of twelve furnaces, including furnaces for tempering the retorts, the total length of the building should be about 150 meters (492 ft.). The width of the room, from the middle of the columns to the middle of the columns is 25.5 meters (83.5 ft.), so that in front of the furnaces is a space of 6 meters (21 ft.), and behind is a space of 2 meters (6.5 ft.), while the furnace is 14.5 meters long (47 ft.). On account of the necessity of a crane for placing the retorts the height of the room to the eaves should be about 15 meters (49 ft.). For the tempering of the retorts and condensers such a plant would need two pit furnaces with movable covers and fired by generator gas. The transportation of the ore is by means of the crane, which is used for fuel for the gas producers as well as by use of the retort crane. At the end of each furnace is the ore bin, which feeds a tram having two bottom discharges and which runs along over the two rows of retorts in the furnace.

The arrangement of the gas producers is also changed. Where formerly it was necessary to have a separate gas producer for each furnace on account of the intermittent firing, the new continuous furnaces can draw from one large common source of gas. More economical operation and better superintendence are possible, and conditions are now right for the recovery of the by-products from the gasification of the coal.

In practice three furnaces may be connected to a gas main fed by two big producers, which are

housed in a room with all the gas pipes necessary, and next to the furnace room. This continuous operation of the producers should result in economies of fuel and labor, but this point was not tested in the experimental plant as the amount of gas consumed in the small furnace was only one-fourth of the output of one of the ordinary producers.

That the results of this test are highly encouraging is beyond all doubt. The number of retorts and condensers for a given output of zinc or for a given amount of ore smelted is reduced to one-third of the former figures, and the number of them used up in a given time was reduced to one-eighth of the former number of retorts and one-twelfth of the condensers, while the refractory materials consumed were only about half to one-sixth of the former figure.

What other advantages may be possessed by the new process, especially with regards to costs of operation, can be seen by the following comparison of the standard Rhenish three-tier type of zinc furnace with the Roitsheim-Remy system.

For purposes of comparison there have been taken a Rhenish smelter with twelve regenerative furnaces, each of 240 muffles, and a Roitsheim-Remy smelter with twenty-four furnaces of forty vertical muffles. If the life of a Rhenish furnace is taken as three years, it can be seen that during each year four of the furnaces are out of commission for two months during rebuilding. With a duty of 3.8 tons for each muffle, we have 4380 (less 250 furnace days) $\times 3.8 =$ roughly 15,700 tons of zinc yearly from the Rhenish plant, or a daily average of 43 metric tons of zinc, corresponding to the daily smelting of 95 tons of ore containing 51.5 per cent Zn and with 88 per cent extraction. The new system of the dimensions mentioned above will have about the same capacity. Taking the life of the new furnace as six years, and remembering that it is out of commission for reconstruction for only a short time (four furnaces out for fifteen days every year), the annual production will be 8760, less 60 furnace days $\times 1.8 =$ about 15,666 tons. The danger of closing the plant on account of labor difficulties is much less with the new plant, for the reason that 40 per cent less labor is required, and of these only a few need be skilled laborers. The simplicity of operation and the small exertion required of the men, as well as the shorter hours which many of them will be allowed to work, will insure much steadier operation. In well-regulated operation extra laborers will not be necessary. A comparison of labor requirements is given in Table I (page 628).

The average wage under German conditions is 5.50 marks in both cases, although the Roitsheim-Remy smelter would be much the more desirable to work in on account of the easier and better labor.

The daily labor expense for the production of 43 metric tons of zinc (or 48.2 short tons) will be:

Old process, $325 \times 5.50 = 1,787.50$ marks (\$426).

New process, $194 \times 5.50 = 1,067.00$ marks (\$254), or 41.57 marks and 24.82 marks per metric ton of spelter (\$8.85 and \$5.27 per short ton of spelter respectively).

The saving of the new over the old process is hence seen to be per ton (metric) of zinc, 16.75 marks, or 40.3 per cent (per short ton, \$3.58).

A further important saving is in the lessened consumption of refractories. The life of muffles in the old method was twenty-eight days, while in the new process it is ninety days, and consequently the corresponding amount of breakage in tempering is greatly diminished—100 retorts per day in the old process and twelve in the new, because there are 2716 (11.32×240) and 954 (23.84×40) retorts, respectively. The consumption

TABLE I—COMPARISON OF LABOR REQUIREMENTS

Figures taken from practice of representative Rhenish smelter. Corresponding labor requirements of the Roitsheim-Remy process

Two series of six furnaces	Two series of 12 furnaces
12 smeltersmen per furnace... 144	2 operators per furnace... 48
2 zinc pullers per furnace... 24	2 stokers per 3 furnaces... 16
2 stokers per furnace... 24	2 repair men per 3 furnaces... 16
2 repair men per furnace... 24	2 overseers per 3 furnaces... 16
2 foremen per room... 24	2 foremen per room... 4
1 general foreman... 1	1 general foreman... 1
6 ash trammers... 6	1 retort crane driver per... 2
6 ash trammers for producers... 6	1 coal and ore crane driver... 2
6 ore trammers... 6	2 machinists per room... 4
6 coal trammers... 6	2 zinc pullers per 3 furnaces... 16
1 muffle trammer... 1	6 ashes trammers... 6
1 prolong maker... 1	1 blacksmith... 1
3 toolsmiths... 3	6 ash trammers for producer... 6
6 extra laborers... 6	4 bricklayers... 4
10 brick masons... 10	2 hod carriers... 2
5 hod carriers... 5	2 extra laborers... 2
30 roustabouts... 30	7 muffle setters per 12 f... 14
	20 roustabouts... 20
Total... 301	Total... 150

Therefore there are 121 men less, or 40.2 per cent decrease.

IN THE RETORT FACTORY

Muffle pressers... 3	Pressing of muffles, etc... 3
Muffle molders... 2	Pug mill, etc, workmen... 2
Brickmaker... 1	Molder... 2
Pug mill, etc... 4	Fireman... 1
Condenser press... 5	Other workmen... 5
Condenser molders... 2	Foreman... 1
Firemen... 2	
Foreman... 1	Total... 14
Muffle trammer and glazer... 2	
Condenser and brick trammer... 2	
Total... 24	

Therefore there are 10 less men or a decrease of 41.7 per cent.

Grand total... 325 Grand total... 194

Hence the total saving in labor is 131 men or 40.3 per cent.

of condensers, calculated in the same way, with life of ten days and 45 days respectively in the two processes, is 320 and twenty-two condensers daily. The amount of material used for luting and other purposes is diminished correspondingly.

There are used in the muffle factory the following weights of refractory material:

In Old Process	In Roitsheim-Remy Process.
100 muffles of 95 kg. 9500 kg.	22 condensers of 35 kg. 770 kg.
Bricks 3000	12 retorts of 400 kg. 4800
320 condensers and tubes 4800	Diverse shapes 2364
Lute, etc. 1200	Bricks 1500
Mortar 300	100 tubes at 3 kg. 300
	Lute material 600
18,800 kg.	10,334 kg.
5% broken and worked over 940	5% broken and re-turned 500
Total... 19,740 kg.	Total... 10,834 kg.

Hence the saving of refractory materials would be 8900 kg. daily, or about 45 per cent.

Aside from the cost of preparing them these products cost about 20 marks (\$4.77) per metric ton, and hence the value of the refractory materials saved is $8.9 \times 20 = 178$ marks (\$42.40) on 43 metric tons of zinc, or 4.14 marks per metric ton of zinc distilled (88 cents per short ton). This saving amounts in one year to 3250 metric tons of refractories or 50,000 marks (\$11,900) in working capital, which referred to 1 ton of zinc at a rate of interest of 5 per cent, amounts to 0.16 mark (3.4 cents per short ton).

This diminished consumption of refractories causes a corresponding saving in fuel in the drying room and in the tempering furnaces.

In the drying room only a third of the former 1000 kg. of coke or 330 kg. are used, causing a saving of 670 kg. at 18 marks per metric ton (\$3.83 per short ton) of 12.06 marks (\$2.87). In the old process the tempering of 100 retorts required three tempering furnaces with a consumption of coal of 2400 kg. per day, while twelve of the present muffles, which take up the room of forty-eight of the old retorts, require two furnaces with a consumption of 1200 kg. of coal (1.345 short tons). The saving in coal is hence 1200×14.00

marks = 16.80 marks. For 1 ton of zinc these two items amount to $28.86/43 = 0.67$ marks (14.2 cents per short ton).

The total savings on the refractories amount to 4.27 marks per metric ton of zinc (\$1.06 per short ton). The saving in tools and machine work is significant.

In Old Process	In New Process
100-120 tools per furnace with wt. of 1200 kg., 500 marks × 12 = 6,000 marks.	30 tools per furnace with wt. of 150 kg. at 50 marks × 24 = 1,200 M. for 24 furnaces.
Repaired and renewed three times annually, 18,000 marks in one year.	The tools consist for the most part of round iron bars (16 mm.) used from time to time to shake down ore that is sticking up in the muffles. They last two years.
15,000/15,700 tons = 1.15 marks	0.5 × 1,200 = 600 marks per year, or 0.04 marks per metric ton zinc.
240 prolongs for each 12 furnaces at 3 marks each, 8,600 marks.	40 prolongs for each of 24 furnaces at 4 marks each = 3,840 M. These are handled very carefully and in the test work showed that a life of two years is certain. Hence 1,920 marks per year, or 0.12 marks per metric ton zinc.
These have to be replaced twice per year, or 17,280 marks, or 1.10 marks per metric ton zinc.	
	The saving from these items is 2.09 marks per metric ton of zinc (or 44.5 cents per short ton).

The removal of cooled ashes will make it easier on the tram cars and trammers when these are used. There will also be a saving in the shovels used. There is doubtless a like saving in the coal for firing the retorts, but as the test plant has never been stopped the exact amount has not been estimated.

The smaller force of laborers will cause further savings. Fewer wash houses and boarding houses, as well as dwellings for the workmen will be necessary, and a corresponding saving in light, water, soap, etc. The increased safety of the work and its added comfort, which means smaller insurance rates, is also of importance.

We are certainly safe in estimating that all these minor savings will amount in all to 3 marks per metric ton of zinc (64.0 cents per short ton), because a saving in the heating fuel of only 5 per cent could amount to 1.85 marks per ton of zinc (39.3 cents per short ton), and the other 1.15 marks corresponds to yearly earnings of 18,000 marks (\$4,290).

Against all these economies we have to consider a greater use of power in the driving of the discharging machines and for pumping the cooling water, as well as for driving the muffle crane. The latter works four hours daily in setting muffles with a cost of 2.60 marks (62 cents). Each discharge apparatus is in commission for about two hours. For the 950 discharging machines the power cost will amount to 10 marks (\$2.38), and the water pumps use power valued at 25 marks (\$5.95). These figures total 37.60 marks (\$8.96), or 0.88 marks per metric ton of zinc (18.7 cents per short ton). Summing up the economies:

1. Saving in labor, 40.3%, or per metric ton	16.75 M. (or \$3.56 /sh. ton)
2. Refractories, etc.	4.87 1.058
3. Tools, etc.	2.09 .444
4. Heating coal and general costs...	2.00 .638
Total	26.81 M. (or \$5.70)
Deducting special power costs...	.85 .18

Per metric ton of zinc... 25.93 M. (or \$5.52 /sh. ton)

Applying this to the saving in the cost of production of a year's output, the new process makes a saving in the production of 15,700 metric tons of zinc of 407,000 marks (17,600 short tons and \$97,000).

Besides these mere advantages in economy we have other important things to consider, such as the increased extraction. As the result of depending less on the care and skill of workmen, there are smaller mechanical losses of ore and metal. The furnaces, as now designed, have much less dead space and are easier to regulate. They are much easier to superintend, and

finally, due to the method of handling the residue, the furnace room is free of fumes, which should mean the saving of a considerable amount of zinc. With zinc worth 450 marks per ton (\$95.75 per short ton, or 4.78 cents per pound), the increase in extraction of 1 per cent means a saving of 80,000 marks in one year (\$19,020). Just how far any single smelter can go in attaining all of these economies depends on the care with which all the various factors are investigated and the designs made accordingly. Such factors are suitable location, the labor conditions, the cost of raw refractories and the possibility of getting the ore into the furnaces with as little stocking as possible. The saving of capital due to good design can be considerable.

The cost of construction of a modern Rhenish furnace with regenerators and 240 muffles, including the equipment for disposing of the combustion gases, but not the gas producers, under Rhenish conditions is about 60,000 marks (\$14,300). A Roitsheim-Remy furnace with forty muffles will cost, at most, 30,000 marks (\$7,150). But since the Roitsheim-Remy furnace produces only one-half the zinc produced by the Rhenish furnace under discussion, the costs of installation of both systems is about the same. What makes the Roitsheim-Remy furnace expensive is the discharging machinery for the retorts. The fitting of each retort with discharging machinery will raise the costs on such a furnace 22,000 marks (\$5,480). But, as has been said above, the wear and tear on these parts is so small that their ultimate cost is negligible. Further, zinc smelters are only too anxious to substitute for the old laborious way of doing things, especially in the discharging of the ashes. Besides the mechanical loading features and the fact that the retort crane does most of the work in replacing the retorts a cheap tram is used for loading the retorts, all of which will cost 300 marks (\$71.50) for each furnace. Exclusive of the retort crane, the cost of the series of twelve furnaces is about 250,000 marks (\$59,600), and besides this two small pieces of apparatus for setting muffles, and costing 6,000 marks (\$1,428). The apparatus for catching the fume on the new furnace is extremely simple, and corresponds to the old fume catchers and ventilating systems. Mechanical power for its operation is not necessary, as the chimney affords enough draft to catch all of this, so that the new smelting rooms will be completely free of fume.

It would hence seem that the discharging machinery, etc., is going to make such a Roitsheim-Remy smelter cost in all about 300,000 to 400,000 marks (\$70,000 to \$95,000) more than the corresponding Rhenish smelter. However, the introduction of loading and discharging machinery of any kind into the latter would cost this much, and such machinery certainly would be adopted if it could be shown to be practical, and even then it would leave much to be desired. But we have to count in the saving in ground space covered, which is about half of the old system, and about the same saving in space is made in the gas-producer room, as well as a considerable saving in the number of gas producers employed. In order to afford space for the retort crane and the ore and coal crane, however, the buildings must be made somewhat higher. The increased cost due to this necessity is more than over-balanced by the savings along other lines. Some of the advantages gained from the 40 per cent reduction of labor are less number of dwellings for the workmen, the lower operating capital for all these things, the possibility of attaining full capacity quickly, and the ease of operation.

Finally, we must not forget that the Roitsheim-Remy process will have a notable influence in improving the environment and the hygiene of the workmen.

May Meeting of American Iron and Steel Institute

The tenth general meeting of the American Iron and Steel Institute was held at the Waldorf-Astoria, New York City, on May 26 and 27. The attendance was very good and the papers covered a variety of subjects of vital interest at the present time.

In his presidential address on "Public Sentiment," Judge E. H. Gary emphasized the necessity of efficient military preparedness, and urged the adoption of laws or amendments to protect American industries. He stated that a large percentage of producers will suffer if the tariff laws are not changed, and also alluded to the necessity of laws or amendments to place our merchant marine on an equality with other nations.

In a paper on "By-products Recovered in the Manufacture of Coke," W. H. Childs emphasized the need of finding outlets for the pitch produced incidental to by-product coke manufacture. The other by-products seem to have ready outlets. In a paper on electric steel, Dr. John A. Mathews said the electric furnace did not come into use to replace other processes, but rather to fill a new demand for high-grade steel. He stated that there were at present 110 furnaces built or building in this country. Other papers read were on "Rail Manufacture," by Dr. John S. Unger, and on "The Distribution of Materials in the Blast Furnace," by G. W. Vreeland. The latter paper dealt chiefly with improvements in practice brought about by the rotating top and distributor.

The annual banquet was held on Friday evening, at which addresses were made by Edward N. Hurley, vice-chairman of the Federal Trade Commission, and Jacob Lowenstein of the American Bridge Company.

The Iron and Steel Market

Some very interesting reactions are taking place within the iron and steel market, while the general position of the steel market is unchanged. The steel market has stopped advancing, as to any really noteworthy movement, while the buying has become very light. The present condition represents the culmination of a trend that has obtained for two months. The heaviest advances in steel prices were in February and March, about equally divided between the two months. April saw relatively small advances, and the advances in the fore part of May were almost inconsequential. In the past fortnight there have been no advances, except in a few descriptions of manufactured steel. Rivets, for instance, were advanced \$5 a ton to 4.25c., while nuts and bolts were advanced 5 to 10 per cent.

Generally it requires the fear of advanced prices to bring buyers of steel into the market for large tonnages. In the great buying movement just closed there was more marked than usual another element, fear that deliveries would not be obtainable at any price if buying were deferred. With nothing approaching a definite prospect that prices will advance farther, with the level already extremely high, and with buyers as a rule well covered for months to come, probably as far as they can foresee the future of their own business, it is natural and inevitable that the market should become very quiet. The business has been put on books and the task now is to fill it.

There are, however, some interesting reactions going on within the market. There was no coherence, and indeed there rarely is much in a general advance, in the respective advances in pig iron, unfinished steel and finished steel. In a general way billets usually advance fully as much per gross ton as finished steel does per

net ton, which does not seem altogether natural for on general principles the spread ought to widen somewhat as higher levels are reached, to make a logical market. Pig iron generally advances not a great deal less than unfinished or finished steel. In this movement the total advances, averaging the various commodities in groups, were about \$6 a ton in pig iron, \$26 a ton in billets and \$28 a net ton in finished steel.

For several months past the preponderating view in pig iron selling circles has been that pig iron would have a further and more marked advance, through exhaustion of pig iron stocks and completion of additional steel making capacity, it being taken for granted that all existing steel making capacity would be kept under the highest pressure for tonnage. The pig iron advance has not occurred, and there are even some evidences of weakness developing. Sales of Southern iron at cut prices, largely speculative iron, have not been uncommon and there have been occasional weaknesses in other markets.

A still more interesting reaction within the general iron and steel market has been the curious decline in billets. There are two remarkable features, that the decline occurred just as large orders for "war steel" were being booked, and that the decline is in prompt rather than forward deliveries. Prompt lots can be bought at lower prices, while forward deliveries are held at as high a figure as has ever been quoted as the market. For plates one must pay about a cent a pound more for prompt delivery than for delivery in the first quarter of next year, while billets can be obtained at about \$5 a ton less for prompt shipment than for regular deliveries over the third quarter, and deliveries in the first quarter of next year would hardly be quoted at all.

Psychology of War Orders

Why should soft steel billets decline when large orders are placed for war steel? The writer does not know, but is strongly inclined to adopt the theory that the stiffness of the billet market in recent months has been due not entirely to the mills being unable to arrange deliveries of billets, through their mills being congested, but largely to their determination to maintain capacity open for any orders for the very profitable "war steel" that might be offered. Sales of war steel in May, including forging billets for export, rolled rounds for domestic makers of shells and for export, probably totaled considerably more than half a million tons in May, but this buying probably concluded the purchases to be expected for any delivery this year. Accordingly the mills knew what they had to count upon, and felt freer to offer soft steel. Another influence presumably is the continued increase in steel making capacity.

The lower prices for billets are for prompt delivery, and represent odd lots accumulating here and there, rather than regular offerings. An assured supply for a period of months would command more, probably as high a price, as at any time. That steel, as steel, should decline at all, however, when finished products remain very strong, suggests a new alignment as to productive capacity. Last September, when the market began to show its remarkable strength, it was the common observation that the strength was simply in steel. Only in wire and merchant bars was there any pressure upon finishing mills; it was a case of finding steel to operate the finishing mills. Now it appears that the pressure is more largely upon the finishing mills, with an augmented production of ingots due to hard driving and the availability, as scrap, of large tonnages of discards occasioned by the manufacture of war steel. The new construction work now in progress looks to the completion, in the next few months, of more steel making than

steel finishing capacity, and thus there is a prospect that this trend will continue.

The future of the steel market in general appears to be well defined. Reinforced by only a very small volume of new business from month to month, and some new business must always be cropping out, the tonnage on the books of the producers will carry them at capacity operations well over the turn of the year. Little is to be expected by way of changes in prices of finished steel. Should the war last through the greater part the steel market would be put to a very severe test. A large part of its foundation at present is the fact that cheap steel is still due customers in large tonnages. All consumers are not forced to pay present prices, and in all probability all could not. Consumption would have to be curtailed. If the war lasts long enough there may have to be a readjustment in steel prices before it ends. Should the war end about the close of this year, or early next year, the event would be the signal for a general readjustment. Enough is known of the manner in which the cost of producing steel has been advancing, through labor and other conditions, to make it very probable that the steel producers will elect to have a general readjustment in costs, to prepare for such good and steady business as may come after the war. They are likely, therefore, to endeavor to maintain prices even though that should act as a decided damper upon buying, with the idea of meeting conditions with appropriate prices, after the necessary readjustments in costs have been effected through a period of a few months of partial idleness.

Pig Iron

The pig iron market has been quiet, except in spots, and has yielded slightly at some points. The Buffalo furnaces have continued their drive noted in the last report and the Buffalo market is quotably lower. Resale Southern iron has gone at cut prices from \$15, Birmingham, while furnaces have sold at this price for second half instead of demanding the premium formerly asked. Basic iron in the valleys is a shade easier, the Republic Iron & Steel Company having bought 15,000 tons at \$18, valley. It bought 15,000 tons of Bessemer at the same time at \$20.50, valley, but other sales have since been made at \$21, the price formerly quoted as the market. There are interesting possibilities in Bessemer iron. There are large requirements abroad, but ocean freights have been considerably more than the cost of the iron delivered at seaboard. There is a possibility of ocean freights declining materially, and this would undoubtedly bring out a demand that would absorb the relatively small tonnages of Bessemer iron available. We quote: No. 2 foundry iron, delivered Philadelphia, \$20.25 to \$20.75; f. o. b. furnace, Buffalo, \$18.50 to \$19; delivered Cleveland, \$19.30; f. o. b. furnace, Chicago, \$19; f. o. b. Birmingham, \$15; f. o. b. valley furnaces, 95 cents higher delivered Pittsburgh; Bessemer, \$21; basic, \$18 to \$18.25; foundry, \$18.50; forge, \$18; malleable, \$18.25 to \$18.50.

Meeting of New York Section of American Chemical Society

At a meeting of the New York Section of the American Chemical Society to be held at Rumford Hall, Chemists' Club on Friday, June 9th, C. Baskerville will report for the Committee on University and Industry. Papers will be presented by George A. Burrell, of the Bureau of Mines, Pittsburgh, Pa., on experiments on the properties of various gases, and by F. E. Wright, of the Carnegie Institute, Washington, D. C., on the petrographic microscope in analysis.

Ore Flotation*

BY WILDER D. BANCROFT

When discussing the theory of ore flotation, people are apt to lay great stress upon surface tension in general and upon contact angles in particular. While this is entirely legitimate, it seems undesirable, because we cannot measure a contact angle with any accuracy and because the actual existence of a contact angle is a matter of doubt.¹ The problem of ore flotation is a very simple one or a very complex one, depending on our point of view. It has been customary to consider it as a very difficult problem, but the other attitude rather appeals to me. There is nothing strange to us in the fact that water wets glass and that mercury does not. We also know that water does not wet greasy glass readily. If one wishes to say that these facts are mysterious, I concede it willingly, because everything becomes mysterious if one follows it back far enough. All I claim is that this is no more mysterious than anything else, and that if we start with these bits of every-day knowledge as given, there are no other serious difficulties in connection with ore flotation. Ore flotation is not a unique phenomenon, it is merely a special case under the broad heading of emulsions.

If a liquid wets a solid, it is adsorbed by the solid, forming a liquid film on the surface of the latter and displacing the air film that was there. If a liquid is not adsorbed by the solid, it does not wet the solid. The formation of a liquid film over the surface of a wetted solid accounts for the experimental fact that the rise of a liquid in a capillary tube is independent of the nature of the walls of the tube. This has always seemed a very improbable state of things, and one that could be justified only by the fact that it was so. It becomes quite simple, however, the moment we consider that the rising liquid does not come in contact with the walls of the capillary tube at all. We are really dealing with the rise of liquid in a liquid tube, and it makes no difference what material is used to support the walls of the liquid tube. That this is the real explanation may be seen from the fact that concordant results are not obtained when a liquid is allowed to rise in a dry tube. To get good results it is important to immerse the tube in the liquid and then to raise the tube.

Since the wetting of a solid is a case of selective adsorption, we should expect that one liquid would wet a given solid more readily than another liquid does, and consequently that the first liquid would displace the second from contact with the solid. No systematic study of this phenomenon seems to have been made, but we know that alcohol will displace oil in contact with metal² and that water will displace kerosene in contact with quartz.³ If we shake a finely divided solid with water and a liquid which is not completely miscible with water, an oil for instance, we can distinguish three cases. The solid is wetted entirely by water, in which case it stays in the water phase and settles to the bottom of it. The solid is wetted entirely by the oil, in which case it stays in the oil phase and sinks to the bottom of it. The solid is wetted simultaneously by oil and water, in which case it passes into the interface separating the two liquids. If the oil is less dense than the water, as is usually the case, it is a little difficult to distinguish between the last two cases. If the non-aqueous liquid is denser than water, chloroform or carbon tetrachloride for instance, it is difficult to distinguish between the

first and third cases. The particles will float if the mean density of solid plus adherent oil film is less than that of the water. They may also float if the action of gravity is not sufficient to overcome the surface tension of the water and thus to pull them through the surface. The maximum weight of substances which can be floated can be calculated from the surface tension under ideal conditions. This calculation applies only when the solid passes into the upper liquid, and does not hold for the case where the solid passes into the interface.

Since we are dealing with selective adsorption, we should expect to find that certain substances would float readily, some others less well, and still others not at all, both the nature of the solid and of the liquid having an effect. This is the case experimentally. Hofmann found that lead iodide, silver iodide, mercuric iodide, mercuric sulphide, and mercuric oxide were floated by ether, butyl alcohol, benzene, kerosene, and amyl alcohol. Copper sulphide, lead sulphide and calcium carbonate were floated only partially by ether, but completely by the other liquids; while zinc sulphide and tin sulphide did not float readily in ether or butyl alcohol, and calcium sulphate was not floated by any of the liquids.

An interesting experiment, which has been done in my laboratory,⁴ is to shake copper powder or aluminium powder with kerosene and water. The metallic powder goes into the kerosene and into the interface, producing an effect of molten copper or molten aluminium, as the case may be. When the bottle is allowed to stand after having been shaken, the metallic powder in the interface creeps up the side of the bottle above the surface of the liquid, rising higher if a little alcohol has been added. I have seen an apparently coherent metallic film rise 2 or 3 in. above the surface of the upper liquid phase. If too much copper or aluminium be added, the kerosene cannot hold all of it up and a portion falls to the bottom of the flask, carrying crops of kerosene with it. If the mixture be poured out on a piece of wood, the copper spreads over the surface of the wood just as it did over the surface of the glass. This experiment illustrates the principle involved in all bronzing liquids. A bronzing liquid consists of a volatile liquid which will hold up the metal, and some substance which will keep the metallic powder from rubbing off too readily after it has been applied. The aluminium and copper powders on the market are coated with stearin. This makes them difficult to wet with water, but special experiments have shown that the behavior of copper or aluminium with kerosene is qualitatively the same whether the stearin coating is removed with ether or not.

Similar results can be obtained with colloidal solutions. Isobutyl alcohol⁵ was added to a colloidal gold solution obtained by reducing gold chloride with carbon monoxide. When the two liquids are shaken, the gold forms a thin film at the interface. This film is violet blue to blue green by transmitted light and golden by reflected light. A thin water film forms between the isobutyl alcohol and the glass, and the gold concentrates in the dineric interface thus formed, making the alcohol appear uniformly gold-plated. With ether the gold film rises high above the level of the two liquids. With carbon bisulphide the adherent film of gold appears blue. When the carbon bisulphide is broken into drops by shaking, each drop appears blue. When a blue gold was obtained by reducing gold chloride with phosphorus dissolved in ether, the gold went into the dineric interface. When a brownish-red gold was obtained in this way, it remained in the water phase and showed no tendency to pass into the interface. This difference is undoubtedly due to an adsorption of some-

*A paper read at the joint meeting of the New York sections of the American Institute of Mining Engineers and the American Electrochemical Society on May 12, 1916.

¹Rayleigh, Scientific Papers, 3, 354 (1902).

²Pockels, Wied. Ann. 67, 665 (1899).

³Cf. Hofmann, Zeit. Phys. Chem. 53, 385 (1913).

⁴Bancroft, Trans. Am. Electrochem. Soc. 23, 294 (1913).

⁵Reinders, Zeit. Kolloidchemie, 13, 235 (1913).

thing at the surface of the gold, because Reinders found that 0.005 per cent gum arabic prevents colloidal gold from passing into the ether water interface. With carbon tetrachloride, carbon bisulphide, or benzene, the gold goes into the interface as before, but the gum arabic prevents its changing from red to blue.

Colloidal arsenic sulphide goes into the dimeric interface with amyl alcohol or isobutyl alcohol, but stays in the water phase when carbon tetrachloride, benzene or ether is the second liquid. India ink goes completely into the interface with amyl alcohol, carbon tetrachloride, or benzene; it goes partly into the interface with isobutyl alcohol, and stays entirely in the water phase when ether is the second liquid.

Winkelblech⁹ has shown that mere traces of gelatine in water can be detected by shaking with organic liquids, the gelatine concentrating at the interface to form a film. "A heavy precipitate was obtained when 10 c.c. of a solution containing 0.234 g. gelatine per liter was shaken with benzene. Precipitates were also obtained when the gelatine solution was diluted tenfold, twentyfold and even fortyfold, provided 10 c.c. solution were taken for the test. At the highest dilution the concentration of the gelatine was 0.06 g. per liter, and there were consequently 0.06 mg. in the 10 c.c. taken for the test. This seemed to be about the limit at which a precipitation could be detected definitely. . . . Some other colloids behave like the glue colloid (glutin), and can be shaken out of their solutions. Other hydrocarbons are also effective, so that the phenomenon seems to be a general one. Precipitation was obtained with albumin, water-soluble starch and soap, as well as with resin dissolved in very dilute caustic soda. The colloids grouped as mucin can be precipitated from urine and the proteins from beer. It is worth noting that tannin can be precipitated but not gallic acid.

"The hydrocarbons which can be used are: kerosene, liquid paraffin, benzene, chloroform, and carbon bisulphide [in addition to benzene]. The result varies from case to case. With the hydrocarbons which are lighter than water, the precipitate floats on the water; with the denser hydrocarbon the precipitate is below the water layer. The emulsions which form seem to have very nearly the same density as the organic liquid used. It is not possible to get the precipitation with all liquids which are non-miscible or slightly miscible with water. Experiments with ether were entirely unsuccessful.

"As a complement to the action of hydrocarbons on aqueous colloidal solutions it was found that fats dissolved in hydrocarbons or similar liquids can be precipitated in the surface film by shaking with water. Precipitations were obtained with butter, olive oil, lanolin, and vaseline. It was also found that the emulsions of heavy hydrocarbons or carbon bisulphide with the fats of low specific gravity also accumulate below the water layer, only a small portion being carried to the surface by adhering air bubbles. When water is used for shaking out, the precipitation is very slight. With a slightly alkaline solution such as dilute lime water, heavy voluminous precipitates were obtained while a transparent layer of fat is obtained when a slightly acid solution is used. With concentrated alkali or acid solutions, viscous emulsions are obtained which hold fast considerable amounts of solution."

Winkelblech patented the use of such organic liquids as kerosene for clearing sewage by shaking out the colloidal oxidizable matter. The method was not a success commercially, because less than 40 per cent of the oxidizable matter was removed.¹

Briggs² has shown that sodium oleate is removed from

solutions of different strengths during the process of emulsifying benzene, and that the amount of this removal depends upon the strength of the soap solution and the specific surface of the benzene phase. Rayleigh³ has observed an interesting case in which dust goes into the water layer. "In the course of some experiments last year, in illustration of Sir George Stokes' theory of ternary mixtures, I had prepared an association"⁴ of water, alcohol, and ether, in which the quantity of alcohol was so adjusted that the tendency to divide into two parts was almost lost. As it was, division took place after shaking into two nearly equal parts, and these parts were of almost identical composition. On placing the bottle containing the liquids in the concentrated light from an arc lamp, I was struck with the contrast between the appearance of the two parts. The lower, more aqueous, layer was charged with motes, while the upper, more ethereal, layer was almost perfectly free from them. Some years ago I had attempted the elimination of motes by repeated distillation of liquid in vacuum, conducted without actual ebullition, but I had never witnessed as the result of this process anything so clear as the ethereal mixture above described.

"The observation with the ternary association, which happened to be the first examined, is interesting, because the approximate equality of the liquids suggests that the explanation has nothing directly to do with gravitation. But the presence of the alcohol is not necessary. Ether and water alone shaken together exhibit the same phenomenon. It would appear that when the two liquids are mixed together in a finely divided condition, the motes attach themselves by preference to the more aqueous one and thus when separation into two distinct layers follows, the motes are all to be found below."⁵

"I have lately endeavored to obtain some confirmation of the views above expressed by the use of other liquids. It would evidently be satisfactory to exhibit the selection of motes by the upper, instead of by the lower, layer. Experiments with bisulphide of carbon and water, and also associations of these two bodies with alcohol, which acts as a solvent to both, gave no definite result, perhaps in consequence of a tendency to the formation of a solid pellicle at the common surfaces. But with chloroform and water, and with associations of chloroform, water and acetic acid (acting as a common solvent) the experiment succeeded. The motes were always collected in the upper, more aqueous, layer, even when the composition of the two layers into which the liquid separated was so nearly the same that a few additional drops of acetic acid sufficed to prevent separation altogether."

The reverse case appears to occur with white lead. J. Cruickshank Smith⁶ says: "During recent years the practice has been adopted, largely among white-lead corrodors who grind their own white lead in oil, of doing away with the final drying of the white lead pulp as it comes from the washing process, and grinding or beating up the pulp (exhausted of water until the proportion of the latter does not exceed about 20 per cent) with a suitable quantity of refined linseed oil. This process depends on the greater surface attraction which white lead particles offer to linseed oil than to water. It enables considerable economies to be effected in the manufacture of ground white lead, and it eliminates risk of lead poisoning during one of the most dangerous parts of the white lead manufacturing process." Not

⁹Scientific Papers, 3, 569 (1902).

⁴Association is here employed as a general term denoting the juxtaposition of two or more fluids. Whether the result is a mixture depends upon circumstances.

⁵The clearness of the upper layer, after a mixture of ether and alcohol has been shaken up with dust, had already been observed and explained, much as above, by Barus, Amer. Jour. Sci. (3) 37, 122 (1859).

⁶The Manufacture of Paint, 92 (1915).

¹Zeit. angew. Chem. 19, 1953 (1906).

²Biltz and Kröhnke, Zeit. angew. Chem. 20, 883 (1907).

³Jour. Phys. Chem. 19, 210 (1915).

enough oil is added to float the white lead and consequently the white lead carries the oil down with it,¹³ leaving the water as upper phase.

That the adhesion between the solid and the liquid may be very marked is shown by the behavior of the so-called water wings. These consist of a closely woven fabric readily permeable to air when dry. When thoroughly wetted, the film of water is strong enough to permit of the wings being blown up enough to float a person with ease. Though I know of no direct experiments on the subject, it seems probable that the gas pressure in some sandstone anticlines may result from the oil being displaced by water, which would wet the porous rock more readily than does the oil.

In many of the cases where oil flotation has been employed we have a sulphide ore, which is much more readily wetted by oil than by water, in presence of a siliceous gangue, which is much more readily wetted by water than by oil. Consequently the gangue tends to stay in the water phase while the ore is carried up by the oil. The use of an acid solution is natural, because oil adsorbs hydroxyl ions,¹⁴ and these latter cut down the adsorption of the solid. Nagel¹⁵ found that when precipitated chromic oxide is shaken with water and benzene, it goes into the dimeric interface, but is precipitated from it by addition of caustic alkali. Zinc sulphide is also precipitated from the dimeric interface of kerosene and water by addition of alkali. I am aware that modern flotation practice is tending to the use of neutral or slightly alkaline solutions, but in such cases air plays an important part, and the use of mixed oils may introduce a new set of factors. It must also be remembered that acid in ore flotation does not act because of a replaceable hydrogen atom, but by cutting down the concentration and consequently the adsorption of hydroxyl ions. If calcium ions, for instance, cut down the adsorption of hydroxyl ions sufficiently, calcium hydroxide would behave like an acid, so far as ore flotation is concerned, though it would be alkaline to litmus paper. Somewhat similar cases are known. Under electrical stress albumin moves to the cathode in acid solutions, and also in calcium chloride solutions. The effect is not a question of acidity. The direction in which the albumin moves depends upon the charge of the ion adsorbed in excess. The hydrogen cation and the calcium cation are each adsorbed more than the chlorine anion, and consequently the albumin moves to the cathode in these two solutions. I do not know whether anything of this sort is a factor in modern flotation practice.

Since no systematic experiments have been made to determine the exact effect of temperature, we do not know to what extent the apparent advantages of a heated solution are due to a relative change in the selective adsorption, to a change in the relative densities of the two liquids, or to a change in the viscosities. It seems probable that all three changes are factors, but that the change in the selective adsorption is the important one. Of course the absolute adsorption must decrease with rising temperature, but the selective adsorption may, and probably does, increase with rising temperature. At still higher temperatures the decrease in absolute adsorption becomes too serious and there is therefore a maximum temperature which is not necessarily the same under varying conditions.

We now have to consider the part played by air in flotation. Since the density of air is low, it is clear that a film of adsorbed air or an attached bubble of air will be very effective in floating a solid particle. If we like,

we may consider air as an extreme case of a second liquid phase, in which case we may have the solid remaining in the air phase under suitable conditions, concentrating in the interface, or remaining in the water phase. If a piece of metal covered with an air film be laid very carefully on the surface of water, the water may wet it so slowly that the metal will float if it is not too heavy. If the surface of a copper wire be converted to sulphide, it will float more readily because the adsorption of air is more marked. If we have a stearin surface, as in the case of copper powder or aluminium powder, the water has still less tendency to wet the solid, and it becomes quite difficult to cause the commercial copper powder or aluminium powder to sink in water. This difference in readiness to wet is made use of in the film flotation processes of Wood and McQuisten.

The concentration of the solid at the interface occurs when a skin forms over the surface of boiled milk or of cocoa or of a peptone solution. I do not know of any case of ore flotation analogous to this, but doubtless one could be devised if anybody was interested in it. In the case of soap solutions we have a partial concentration in the surface, but the bulk of the soap remains distributed through the water phase. The soap, however, adsorbs so much air that boiling-point determinations on concentrated solutions are worthless.¹⁶

The selective adsorption of gases and vapors by solids is a matter of common knowledge.¹⁷ The film of condensed gas shows itself in the abnormal mobility of very fine powders, in the fact that two pieces of a broken object will not reunite when pressed together, in a resistance to the passage of an electric spark between solid terminals, and in the behavior of the crystal detector and the coherer as used in wireless telegraphy. All liquids show selective adsorption of gases and vapors. The most striking way in which this shows itself is in the form of the splashes when a drop of water, 5 mm. in diameter, falls on a sheet of water from a height of less than 1 meter. It is this film of adsorbed gas which tends to prevent the coalescence of two soap-bubbles or two impinging jets of water when there is no electrical stress.

Since water removes air more or less quickly from practically all minerals, selective flotation from already wetted ore is practically impossible, and one must have recourse to the combined effect of oil and air. It so happens that in acid or neutral solutions air seems to be adsorbed by organic liquids much more readily than by water.¹⁸ Into 100 c.c. approximately normal caustic potash solution 0.5 c.c. chloroform was dropped from a 5 c.c. pipette. The chloroform did not seem to spread out on the surface before sinking so much as it did with water. The globules sank to the bottom and flattened out; they were distinctly not very mobile, and seemed to sink to the bottom of the vessel. When the chloroform was dropped into the water it broke up into a number of drops which did not agglomerate so easily as in the water solution. In fact, quite a little shaking was necessary in order to make them coalesce. At first no air bubbles could be detected, but after standing for five minutes a very small bubble appeared on the chloroform. Sulphuric acid was then added until the solution became acid. The flattened drop of chloroform at once assumed the shape of a round ball and became mobile. An air bubble also appeared in the center of the drop.

"Into 100 c.c. approximately normal sulphuric acid solution 0.5 c.c. chloroform was dropped as before. The chloroform spread all over the surface and then sank

¹³My attention was first called to this by Mr. T. R. Briggs.

¹⁴Twomey, Jour. Phys. Chem. 19, 360 (1915).

¹⁵Jour. Phys. Chem. 19, 570 (1915).

¹⁶McBain and Taylor, Zeit. phys. Chem. 76, 182 (1911).

¹⁷Bancroft, Jour. Phys. Chem. 20, 1 (1916).

¹⁸Twomey, Jour. Phys. Chem. 19, 360 (1915).

through the solution in small drops, forming round globules with air bubbles clinging to each. It was hard to get rid of the bubbles on the chloroform drops by shaking; as soon as one was driven off another bubble appeared exactly in the center of the drop. When the bubbles were dislodged from the drops, they rose to the surface carrying with them some chloroform, a part of which remained on the surface until it evaporated, while the rest sank back to the bottom of the solution. The globules were very mobile and coalesced readily. Cautic potash was added to the solution, making it alkaline. The chloroform globule flattened immediately and the air bubble in the center disappeared. In still another experiment an acid solution was made alkaline, then acid, and then alkaline again. The result confirmed Wilson's experiments,¹⁹ for the drop of chloroform was always flat in the alkaline solution and always round in the acid solution. There is scarcely any difference to be noted between the shape of the drop in acid solution and in pure water. The same results were obtained when NaOH and HCl were substituted for KOH and H₂SO₄.

"In one experiment in a nitric acid solution the temperature was raised to about 40 deg. C. Bubbles seemed to shoot from all parts of the solution to the chloroform drop. When they had formed a large bubble in the center of the chloroform, the air bubble rose to the surface of the solution as in the other cases."

Of course, it does not follow that the relative adsorption of gas is always greater for oil in acid solution, but merely that this seems to be true in the cases hitherto studied. It is purely an empirical observation. Another interesting fact is the difficulty that is experienced in getting air bubbles to attach themselves in some cases to the oil films surrounding the solid particles. Some people have even claimed that nascent gas is essential, but this is absurd. If the air bubble comes in contact with the oil it will adhere; but it is not easy to bring about this contact. It can be done by vigorous agitation or by causing dissolved gas to come out of solution, but the essential thing is merely to bring the gas in actual contact with the oil.

A large air bubble will have a relatively great lifting power, but it will also tear loose very readily from an oiled particle. We shall get better results if we produce a froth consisting of bubbles of air in oil. Under ideal conditions the film around the bubbles will consist of particles coated with oil. We cannot get a froth with a pure liquid and air. There must be present a third substance in colloidal solution which will tend to form an emulsion of air in the liquid in question, for a froth is essentially a very concentrated emulsion of air in liquid. If the colloidal material is not present in the liquid it must be added. It has often been overlooked that what is needed for ore flotation is a froth of air in oil. People have said to themselves that froth is what is needed and have added saponine and other things with disastrous results. Saponine produces a froth, but it is a froth of air in water and therefore plays havoc with flotation. The things which have proved successful are substances like sodium resinate so called, which produces a froth of air in water in an alkaline solution but one of air in oil in an acid solution, because free rosin forms a colloidal solution in oil but not in water. Mr. Van Arsdale has worded the matter in what seems a different way by saying that the substance added must tend to emulsify water in oil and not oil in water. This is very nearly the same thing, because substances which form colloidal solutions in oil and not in water tend to emulsify water in oil.²⁰ I

have preferred to consider the oil-air interface and Mr. Van Arsdale the oil-water interface, but the two points of view lead to the same conclusions in almost all cases.

So far, we have been considering the case where we have a fair amount of oil. If we cut the amount of oil down almost to a vanishing quantity another factor comes in, namely, air flotation. When sufficient quantities of oil are used, the air floats the oil and the oil floats the ore. The ore is inclosed in a drop of oil having the properties of matter in mass and sinks to the bottom of the drop of oil, distorting it to a greater or lesser extent. If the amount of oil is decreased sufficiently, we no longer have an oil drop surrounding the particle of ore, but an oiled particle, the lower part of which is, or may be, in contact with water, while the upper part is in contact with air. We are therefore getting air effect in addition to the oil effect. I do not know the relative importance of these two effects, but it has been claimed—and disputed—that the modified air flotation is of much greater value than the other. In the Wood and the McQuisten processes there is no doubt but that the separation would be more effective if it were possible to cover the ore particles with a thin film of stearin, leaving the gangue particles uncoated. It is very difficult to wet the stearin-coated commercial copper and aluminium powders, and it is therefore very difficult to make them sink under water. In the modern processes of ore flotation using very little oil per ton, we get a thin coating on the ore analogous to the stearin coating on the copper or the aluminium powder. It is possible that the air film may surround the oiled particle completely so that the oil does not come in actual contact with the water. In that case we are back to a straight air flotation of oiled particles. This point calls for further study because, if established, it would have a very important bearing on the future development of the subject.

It is under these circumstances that addition of more oil causes the ore to cement together and sink. The reason for this will perhaps be seen more easily if we consider the analogy of sand and water. When enough water is mixed with sand, we get a quicksand over which it is unsafe to walk. With only a little water we get a plastic mass over which it is a pleasure to walk and out of which children can make forts, pies, etc. When the sand dries out more, air gets in between the grains, and the walking becomes hard, though the sand is by no means dry from a chemical point of view. When the amount of oil round the ore particles is sufficiently small, the air gets in and makes a froth possible. With more oil we get a plastic mass; with still more we get the bulk oil process.

Anderson²¹ classifies flotation oils as "frothing" and "collecting" oils.²² "There is at times some difficulty in grasping the distinction between frothers and collectors as such, for one oil in itself may, and often does, possess both frothing and collecting properties. The action of a frothing oil is such as to produce froth in greater or less amount, dependent on the frothing power of the oil. A collecting oil has a collecting power for sulphides in preponderance over its frothing action, being therefore, so to speak, a poor frother; a collecting oil may have simply a collecting action and little or no frothing action. As stated in the foregoing, some oils combine both the properties of frothing and collecting in variable degrees of each.

"The most successful frothing oils include the pine oils, cresylic acid and turpentine and other pyroligneous products from the distillation of wood—notably methyl alcohol.²³ The coal tar phenols and their near

¹⁹Wilson, Jour. Chem. Soc. 1, 174 (1848).

²⁰Bancroft, Jour. Phys. Chem. 17, 515 (1913).

²¹Met. & Chem. Eng. 14, 136 (1916).

²²Van Arsdale calls them "frothers" and "oilers."

²³This must be an error. W. D. B.

derivatives, and almost all of the so-called essential oils are good frothers. The essential oil of eucalyptus finds favor, particularly in Australian practice, on account of relatively low cost and immediate supply. Castor oil, to which reference has already been made, when mixed 1:4 with kerosene has found application. The more volatile products of petroleum, including kerosene and gasoline [?] have been successful frothing oils."

"So-called mineral oils and tar oils do not generally form a good flotation froth, but have a marked selective action on the sulphide minerals. Among the mineral oils are included the following: asphaltum base, crude petroleum, refined oil, gasoline, burning oil, creosol, and coal-tar creosotes."

"It is found that thick oils tend to form viscous, coherent flotation concentrates, while thin oils form less coherent masses. The action of coal tar in stiffening a weak, ephemeral froth is indicative of the former. In general the essential oils give a coherent froth and satisfactory extraction; oils like oleic acid or candle-maker's red oil, petroleum, and lubricating and engine oils have a strong tendency to produce heavy, thick granules which will not float. Oleic acid has a well-marked power to float silicates."

If a pure liquid does not form a froth with air, it follows that no oils can be frothing oils except in so far as they contain suitable colloidal material suspended in them. In some cases this colloidal material is rosin; in other cases it is for the organic chemist to decide just what the special substance is. Since the good effect of the frothing oils is due to the colloidal substances, it is a question of cost whether it is more advantageous to mix a frothing oil with a collecting oil or to add the constituent which makes the former a frothing oil.

Since we are dealing with selective adsorption, we should expect to find that some oils would be better than others for certain purposes.

Anderson² states that "oils derived from the destructive distillation of wood, such as wood creosotes, pyroigneous acid, and the like, are found to give the best recovery on galena and zinciferous material; coal-tar products are better adapted to the successful flotation of copper-bearing minerals." There are no independent data from which this result could have been predicted.

Since flotation is due to selective adsorption, anything which will change the latter will change the degree and nature of flotation as far as the oil-water flotation is concerned. Adding a third liquid which is miscible with the other two, will tend to make the oil and water layers more nearly alike in composition and therefore in properties. This gives us a possibility of varying the selective adsorption within certain limits and its possibilities should be determined, even though there may be no economic advantages. Now that we are a little more clear as to the cause of frothing, it becomes possible to study new frothing agents more successfully and it is possible that some of these might have distinct collecting powers of their own. In some experiments recently made at Cornell by Mr. Briggs, it has been found that addition of salt made it easier to shake out colloidal ferric oxide with benzene. The reason for this seems to be that the salt makes the colloidal solution less stable. Any substance which prevents peptization in the water phase or promotes it in the oil phase will tend to increase the flotation. I do not yet know to what extent this is applicable to ore flotation; but Anderson² reports that experiments performed on a 60-mesh product from the Joplin district containing pyrite and galena in a calcareous gangue showed: that potas-

sium bichromate will deaden galena and permit the flotation of the pyrite; that sodium, potassium, and ferric sulphates promoted the production of clean concentrates; and that ferrous sulphate and cupric sulphate were very harmful to the successful flotation of this particular product, flotation being practically impossible in their presence. Anderson, of course, ventures no opinion as to why these salts act in this way; but it ought not to be difficult to work out a hypothesis if some data were forthcoming. The inadequacy of the present data is made clear by the statement of R. H. Richards that in the case of a certain Tennessee zinc ore the addition of a small amount of copper sulphate was necessary in order to bring about successful flotation. We have not yet made any experiments on the factors affecting the air flotation when the oil is reduced to a minimum, so I will not discuss that point at all.

There seems to be no reason to suppose that ore flotation has yet gone beyond the first stages of its development, and certainly a clear knowledge of the general theory should be a help in promoting the development.

Cornell University.

Newark Industrial Exposition

The Industrial Exposition being held at Newark, May 13 to June 3, in the First Regiment Armory, Jay Street (reached by Central Avenue trolley), is representative of the large manufacturing interests of that city. The exhibits are nicely arranged and include a large variety of industries. Among the industrial concerns having space are the following:

Gamon Water Meter Co., water meters.
Standard Oil Co. of New Jersey, Polarine oils and lubricants.
Newark Wire Cloth Co., wire cloth for industrial purposes and screens up to 300 mesh.
Crocker-Wheeler Co., generators, motors.
Westinghouse Electric Co., generators, motors, meters, Westinghouse Mazda lamps.
Murphy Varnish Co., varnish pigments, oils, small grinding rolls, filter presses, etc.
Celluloid Co., celluloid articles.
Driver-Harris Wire Co., Nichrome heat-resisting metal, Monel metal wire, small-wire drawing machine, demonstrating the drawing of copper wire from 0.016 in. to 0.0063 in.

Newark Leather Machinery Company, and combined exhibits of Newark's leather companies showing different leathers manufactured.

National Oil & Supply Co., Viscos oils and greases.
Combination Rubber Mfg. Co., hose, packing, etc.
Thomas A. Edison, chemicals, phenol, aniline, etc.
Edison Storage Battery Co., Alkaline storage battery.
General Electric Co., Edison Lamp Works, Mazda lamps, historical exhibit showing development of incandescent lamp.

Anti-Hydro Waterproofing Co., waterproof liquid, waterproof paint, for brick, concrete, etc.

F. W. Horstmann Co., McDowell feed-water heater and purifier.

Bureau of Standards Analyzed Samples.—The Bureau of Standards, Washington, D. C., now has ready for distribution a new sample of its iron D, No. 6-b, replacing No. 6-a, which has been long out of stock. The composition of the new sample is: carbon, 2.39; graphite, 1.79; silicon, 2.59; titanium, 0.077; phosphorus, 0.531; sulphur (grav.), 0.046; manganese, 1.54; copper, 0.044; chromium, 0.014; vanadium, 0.025; nickel, 0.026. Until printed certificates can be had a provisional certificate of analysis, without details, will be furnished with each sample issued.

¹Met. and Chem. Eng. 14, 136 (1916).

²Met. and Chem. Eng. 14, 137 (1916).

The Distribution of Silver Between Metallic Lead and Litharge-Containing Slags

BY BOYD DUDLEY, JR.

In the fire assay of gold and silver ores by the crucible method it is the intention to effect complete decomposition of the ore by heating it, in the finely powdered state, in contact with suitable fluxes, and simultaneously to produce throughout the resulting slag a collector of gold and silver, consisting of small globules of metallic lead. When the fusion is complete, the lead collects as a liquid mass in the bottom of the crucible with the liquid slag above it. The lead is separated from the slag by pouring the fusion into a cone-shaped mold and there allowing it to freeze, whereupon the slag may be broken from the lead. The gold and silver collected by the lead during the fusion are recovered from it by cupellation.

Errors in the Crucible Assay

While complete collection by the lead of all gold and silver that may be present in the ore is the desired end in the crucible fusion, this result is generally not achieved. Various causes are responsible for the failure of the lead to completely fulfil its function. These are usually referred to as sources of error in the determination, or as just "losses," and they may be classified as follows:

1. Mechanical loss of material from the crucible may be caused by "dusting," by which term is meant the expulsion of dust from the crucible by gases that escape from the charge before fusion begins, or before fusion is sufficiently far advanced that the particles of ore are attached to, and weighted by, portions of slag. Mechanical loss from the crucible may also be caused by spitting or boiling-over during the fusion.

2. Due to an improper selection of fluxes, coarseness of the ore grains, insufficient time, or to other causes, a part of the ore may remain in the undecomposed condition at the time the assay is removed from the furnace. If the undecomposed particles happen to inclose gold or silver, or both, the amounts so inclosed will, of course, remain suspended in the slag.

3. There may be imperfect aggregation of the lead at the end of the fusion, or when the assay is poured shots of lead may become detached from the main body. With either of these conditions globules of lead may remain in the crucible or suspended in the slag, and in such cases, even if the decomposition of the ore is perfect and if the collection of the gold and silver by the lead is as complete as is possible, the assay is obviously defective. The error thus introduced is generally proportional to the amount of lead detached.

4. At assay temperatures gold and silver are both slightly volatile, and a small loss from the crucible may result from this cause.

5. Finally, it is necessary to consider the fact that with all other conditions perfect the lead will be unable to collect all of the gold and silver from the slag, because the slag possesses the power to dissolve these metals or compounds of them just as the lead dissolves the metals themselves. In other words, at the conclusion of the fusion the gold and silver will be distributed between the lead and the slag in a fairly definite manner, though the lead will have nearly all of the precious metals and the slag only a little.

The first three causes of error may, as a rule, be entirely prevented by the proper selection of fluxes and conditions. Although there is always a chance in pouring an assay that globules of lead may become

detached from the main body and may not again reach it before the slag solidifies. It may be well to note that errors due to this cause are quite frequent with slags containing excessive amounts of soda, which seem to prevent the lead from collecting as a single mass. Also, when the inner surface of the crucible becomes badly pitted and corroded during the fusion, shots of lead that cannot be poured from the crucible are more frequently observed than when the crucible is corroded to a less extent or in a more uniform manner.

The volatilization loss of gold and silver during the crucible fusion is probably negligible, because by the time the temperature of the charge has increased to the point where pure gold and silver might be appreciably volatilized, these metals are then present in the form of a very dilute solution in lead. In this condition their vapor tensions will be greatly reduced, and their tendency to volatilize correspondingly decreased.

It is with the fifth cause of error that the present paper deals, and then only with the case of silver. The retention of gold by slags was not studied.

The above rather exact classification of metal losses in the crucible fusion has been given in order to make clear the significance of the results obtained in the experiments described below. It is particularly desired to emphasize the distinction between the losses due to the second and third causes and that due to the fifth. As a general rule the errors due to all of these causes are collectively referred to as "slag losses," but it should be evident that the two first-mentioned are produced by purely physical conditions, while the last is essentially the result of a chemical phenomenon.

Equilibrium in the Crucible Fusion

In considering the case of the retention of gold and silver by assay slags its similarity to well-known cases of distribution equilibrium is apparent. In general, when two immiscible phases are in contact and a third substance soluble in both is added to them, a part of it will pass into solution in one phase and a part in the other. If opportunity is offered for the establishment of equilibrium, the solute will distribute itself between the two solvents in a perfectly definite manner, which is dependent only on the nature of the substances involved and on the temperature.

A simple case, wherein the solute occurs almost wholly in the same molecular state in the two solvents, is the distribution of succinic acid between ether and water.¹ When a small quantity of succinic acid is shaken with a mixture of ether and water, a state of equilibrium is attained, the conditions of which may be studied by allowing the two immiscible liquids to separate and determining the concentration of succinic acid in each. The results of such experiments conducted at constant temperature are given in Table I, wherein C_1 and C_2 denote the number of grams of acid dissolved in 10 c.c. of water and ether respectively.

TABLE I.—EQUILIBRIUM CONCENTRATIONS OF SUCCINIC ACID IN MIXTURES OF ETHER AND WATER AT CONSTANT TEMPERATURE

C_1	C_2	C_1/C_2
0.024	0.0046	5.2
0.070	0.013	5.2
0.121	0.022	5.4

It may be seen that here the ratio of the concentrations of the solute in the two immiscible phases is a constant at constant temperature, and is independent of the relative amounts of the two phases and of the

¹Nernst, Theoretical Chemistry, trans. 6th Ger. Ed., p. 496.

amount of the solute involved, so long as the solutions are sufficiently dilute. This condition is characteristic of those cases of distribution equilibrium where the solute occurs in the same molecular state in both phases, i.e., where a single molecular species is distributed between two immiscible liquids.

When the solute does not exist in the same molecular state or possess the same molecular weight in both phases, a state of equilibrium may be established in the same manner as in the above example, but there may not be the constant relation between the equilibrium concentrations that obtains in the simpler case. However, the fact remains that, whether the solute exists as a single molecular species in both phases, or whether chemical reactions occur within the phases and the solute exists in different molecular states in them, a state of equilibrium is generally attainable, the characteristics of which are dependent only upon the nature of the reacting substances and upon the temperature.

On first thought it may be difficult to perceive that these facts have any particular application to assaying. But they have—and not only to assaying, but to all metallurgical processes in which immiscible liquids are produced, such as metal and slag, matte and slag, matte and metal, etc. Without doubt, such equilibria are not only possible but the attainment of equilibrium conditions is even probable in the removal of impurities from white metal when the "selecting" process is in use, in the removal of impurities from iron and steel by washing the metal with slag, and in other processes of like nature. Furthermore, the question of metal losses in slags during smelting operations can be studied in a rational manner only when due consideration is given to the possible distribution equilibria that may be involved. Examples of such cases are the slag loss of copper in matte smelting, and the slag losses of lead and silver in lead smelting.

Returning to the specific case of the crucible assay, in the properly conducted fusion metallic lead is reduced in the form of innumerable liquid globules, which are disseminated throughout the entire charge at the time that the slag-forming constituents start to unite. These particles of lead remain suspended in the slag and are thoroughly agitated in contact with it during the boiling stage of the fusion, the boiling being produced by the expulsion of such gases as carbon dioxide, sulphur dioxide, etc., as are formed by the union of the various constituents of the charge. In the course of this agitation of lead and slag, while the two are in intimate contact, the free particles of gold and silver naturally become alloyed with the lead, while those particles of gold and silver that have not been liberated must await collection by the lead until their encasing or attached particles of gangue are dissolved in the slag. With this fact in view the importance of having lead suspended in the slag until the decomposition and dissolution of all ore particles is complete is quite evident.

Assuming complete decomposition of the ore to have been attained, some of the gold and silver may at first enter the slag in the dissolved condition, but, due to the thorough stirring of the charge by boiling and due to the large area of contact between the lead and the slag that results from the minute state of subdivision of the lead, almost perfect conditions obtain for the lead to remove from the slag such of this dissolved gold and silver as it can. On the other hand, if all of the gold and silver particles have been crushed free from the gangue and in consequence are collected by the lead in the early stage of the fusion, the agitation of the lead and slag will enable the slag to

remove such gold and silver as it can from the lead. In other words, the conditions are almost ideal for establishing that state of distribution equilibrium of gold and silver between lead and slag as corresponds to the nature of these substances and to the temperature of the fusion at the time.

If the process could be arrested just at the conclusion of the slag formation and as the lead is settling to the bottom of the crucible, and if the lead and slag could be completely separated from each other and analyzed, the results would doubtless indicate the truth of the above statements. However, the practical difficulties in the way of completing such an experiment are many, so for the present there is no direct evidence on this point.

Following the course of the crucible fusion still further, as the formation of the slag approaches completion and as its viscosity decreases due to increasing temperature, the smaller globules of lead coalesce to form larger ones, and the lead gradually settles through the still boiling slag to the bottom of the crucible. Here it should collect as a single liquid mass with the slag above. As a rule the slag continues to boil for a considerable time after the lead has reached the bottom of the crucible. The expulsion of gas from the charge is not yet complete, and the boiling produced by its continued evolution serves to still further agitate the slag in contact with the lead, though at a greatly reduced rate as compared with the agitation which occurs while the lead is suspended in the slag.

The agitation produced by the boiling of the slag after the lead has settled is accelerated by the presence of convection currents, which are caused by unequal temperatures within the crucible. Such currents are almost invariably present, and their action, as well as the effect of boiling, can be readily observed by watching the course of a crucible fusion in a pot furnace or in any furnace in which the surface of the slag is visible. Convection currents are produced in all cases where differences of temperature exist in different parts of the crucible, and such differences continue to exist until the very instant when the crucible and its entire contents arrive at the temperature of the surroundings. Moreover, the surrounding temperature must be uniform in the vicinity of the crucible in order to produce a perfectly quiescent fusion. Since these conditions are seldom or never encountered in the assay furnace, it is clear that, after all boiling due to the evolution of gas from the slag has ceased, the convection currents continue to remove the slag in contact with the surface of the lead and to replace it with fresh slag. The action of convection currents in thus stirring the slag after all boiling has ceased is a matter of common observation among assayers who have taken the trouble to watch for it.

It thus becomes evident that the possibility of establishing a distribution equilibrium of gold and silver between lead and slag does not cease to exist when the lead settles to the bottom of the crucible. Nor does the equilibrium that may be established while the lead is suspended in the slag necessarily persist after the metal has settled. On the other hand, if the temperature continues to rise, the continued boiling of the slag, coupled with the action of convection currents, will offer some opportunity at least for that readjustment of the equilibrium, which would tend to occur in response to the increase in temperature. Likewise, it is evident that such particles of gold and silver as may not be set free from attached particles of gangue up to the time when the lead settles from

the slag, are not hopelessly lost. If the temperature at the end of the fusion is sufficiently high, and if enough time is allowed to insure the complete dissolution of such encasing gangue particles, the gold and silver which they hold will have opportunity to reach the lead.

The above outlined course of a crucible fusion represents the ideal process. How closely the ordinary assay approaches this ideal is a question that can only be answered by a large amount of carefully conducted experimental work, which up to the present has not been attempted. But in this paper a few facts in regard to the final ideal conditions are presented.

Determination of Equilibrium Conditions

The experiments described below were undertaken with the intention of studying the effect of temperature and of slag composition upon the distribution of silver between metallic lead and certain commonly used types of assay slags. While the work is incomplete, it is thought that the results secured are of considerable value in indicating the effects of the factors mentioned, and also they perhaps offer some evidence in regard to the nature of such slag losses in general.

The method employed is simple in outline, but the manipulative details are somewhat tedious and troublesome. In each experiment two crucible charges containing the slag-forming constituents in the desired amounts are prepared. They are identical in composition with the exception of the silver content. To one a quantity of silver is added, which imparts to the fused slag a higher silver concentration than corresponds to the ultimate equilibrium concentration. To the other less silver is added than corresponds to this concentration. In all cases the silver is added in the form of an argentiferous litharge of known silver content, which is prepared by adding a solution of silver nitrate to finely powdered yellow litharge, drying the mixture, passing it through a 100-mesh sieve, and determining the silver in the product by corrected assays. At first it is necessary to guess at the amounts of silver to be employed, but as the work proceeds very close estimates of the amounts required can be made.

The crucibles and charges are introduced into an electric resistance furnace, and the charges are fused. The furnace is then brought to the desired temperature, which can be maintained within ± 3 deg. C. for considerable periods of time by regulating an external resistance in series with the furnace winding. When the desired temperature has been attained, a button of lead containing a known amount of silver is dropped into each crucible, the quantities of lead and of silver being the same in both cases. Then, by means of clay stirrers, which have been previously brought to the temperature of the furnace, the slags are thoroughly and rapidly stirred. In this manner an opportunity is offered for the establishment of equilibrium conditions in the distribution of silver between the lead and the slag. That such an equilibrium is attained is shown by the fact that in the one crucible containing the silver-rich slag the silver passes from the slag to the lead, while in the other crucible the reverse of this action occurs. In the end both slags attain the same concentration with respect to silver.

After stirring, which is continued for from 15 to 60 min., depending on the viscosity of the slag, its tendency to corrode the crucible, and whether the stirring is done manually or mechanically, the crucibles are removed from the furnace. The slag and lead

are not poured as in the ordinary assay, because of the danger of detaching globules of lead from the main body. If this occurs and if one or more small globules remain in the slag and are not discovered before the slag is assayed, the results are worthless. This is true because the concentration of silver in the slag is so small in comparison with its concentration in the lead that the inclusion of even a minute globule of the silver-rich lead introduces a very large error. On this account only about four-fifths of the slag is poured from the crucible, the remainder being allowed to remain with the lead. The poured portion serves as a sample of the slag. It is crushed and screened through an 80-mesh sieve, and a weighed portion, 100 to 150 g., is assayed for silver.

In assaying the slag 3 to 4 g. of argol is added, and the resulting charge is fused and poured. The lead button, weighing from 25 to 30 g., is cupelled in the usual manner. All of the slags that have been studied contain enough litharge to permit the application of this method. In some cases a little soda is added to replace the litharge reduced; in others borax glass is added to reduce the corrosive effect of the slag upon the crucibles. That this method makes a sufficiently complete recovery of the silver for practical purposes is shown by the fact that numerous assays of the second slag have recovered amounts of silver ranging from nothing to only half of 1 per cent of that recovered in the first assay.

The slag and lead left in the original crucible are allowed to freeze, after which the button of lead is recovered by breaking the crucible. It is weighed, and, from the final weight and the amount of silver originally added to the lead, the concentration of silver in the metal is calculated. Usually the amount of silver that passes from the slag to the lead or from the lead to the slag is so small a proportion of the total present in the lead that it may be neglected.

The furnace in which the slags were formed and held at constant temperature was constructed by winding an ordinary clay muffle (Battersea KK) with Chromel resistance wire, the strands being 0.5 in. apart. After the wire was in place the outside of the muffle was plastered with a mixture of fine dead-burned magnesite and sodium silicate solution. The muffle was then placed with the open end up in a Rockwell Engineering Company stationary, oil-fired furnace, which could be temporarily spared for the purpose, and the space between the muffle and the lining of the furnace was packed with a mixture of light-calcined magnesia and asbestos. Reference to Fig. 1 will make clear the details of furnace construction. In this figure are also shown the positions of the crucibles, stirrers, and pyrometer.

With the crucibles in place and after a state of thermal equilibrium had been established, the variation of the muffle temperature from the bottom of the crucibles to the level of the slag line was less than 5 deg. C. In controlling the temperature during an experiment the thermo junction was placed between the crucibles and 1.5 in. above the crucible support, this point being about the average elevation of the charges during the stirring. All temperature measurements were made with a platinum-rhodium thermocouple, which was protected by a fused silica tube. The indicating instrument was a W. Paul millivolt meter, and the cold junction of the couple was maintained at 0 deg. C.

The stirrers were made of Woodland fire-clay crushed through a 40-mesh sieve, mixed with an equal volume of crushed crucible scraps of the same size. The mixture was made plastic by the addition of

water, and molded into cylinders, 4½ in. long by 1½ in. in diameter, with a round hole in one end ½ in. in diameter by 1½ in. deep. After slow drying, the cylinders were burned at about 1250 deg. C., and then mounted on a No. 10 B. & S. gage Chromel wire. A spiral on the end of the wire was inserted into the hole in the clay piece and cemented in place with a mixture of magnesite and sodium silicate solution.

During an experiment a clay piece dips into the slag in each crucible, and the ends of the wires project through the lid of the furnace. By raising and lowering the stirrers the slags are very effectively agitated in much the same manner as is the cream in an old-fashioned, vertical-dasher churn.

A small motor was harnessed to a "walking beam" as is shown in Fig. 1, and at low temperatures, when the

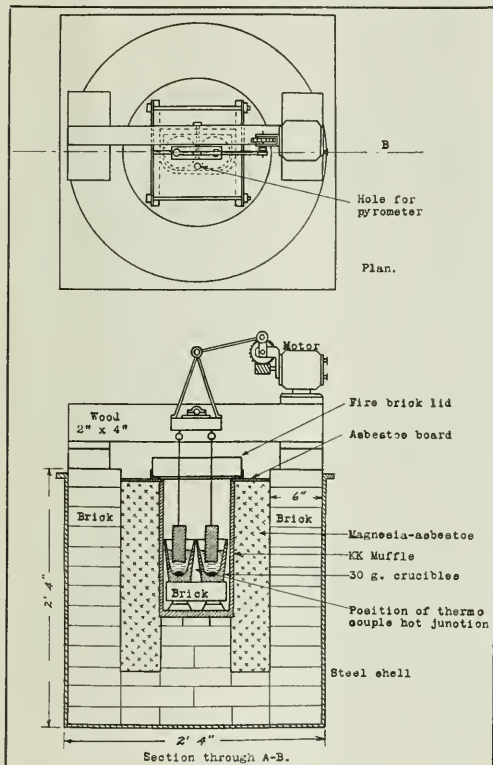


FIG. 1—ELECTRIC FURNACE

slags were viscous and not too corrosive to the crucible, the stirrers were suspended from the ends of the beam. The beam made about 60 oscillations per minute, and by the use of this device much of the tedium of hand stirring was avoided.

Compositions of Slags Investigated

The compositions of the slags that were worked with, exclusive of the amounts of silver, are shown in Table II. Table III shows the quantities of various reagents required to produce 100 g. of these slags.

It will be seen that these slags range in composition from 25 per cent litharge to 90 per cent litharge, and in oxygen ratio from 1.71 to 0.48. Only the commonly used reagents were employed, and slags containing oxides of metals other than lead were not studied. While these compositions will, of course,

TABLE II.—COMPOSITIONS OF SLAGS

Slag No.	Na ₂ O, Per Cent	PbO, Per Cent	SiO ₂ , Per Cent	B ₂ O ₃ , Per Cent	O in Acid, O in Base
1	4.24	89.7	3.58	2.48	0.48
2	3.15	85.0	7.00	4.85	1.02
3	12.65	71.65	10.74	4.96	1.08
4	24.79	48.30	24.12	2.79	1.50
5	38.78	24.90	31.14	5.18	1.71

TABLE III.—REAGENTS FOR 100 G. OF EACH SLAG

Slag No.	Na ₂ CO ₃ g.	PbO g.	SiO ₂ g.	Na ₂ B ₄ O ₇ g.
1	5.36	89.70	3.58	3.58
2	1.71	85.00	7.00	7.00
3	17.90	71.65	10.74	7.10
4	40.25	48.30	24.12	4.03
5	60.60	24.90	31.14	7.48

not find favor with everyone as being suitable for practical assaying, they do serve the purpose of indicating the effects of the principal factors that govern the solution loss of silver in the slag. Consideration of the experimental results will show that these factors are the percentage of litharge and the temperature.

None of the materials employed in the crucible charges was subjected to any special preparation, excepting the soda. This was calcined at a temperature near its melting point in order to remove water and to dissociate any bicarbonate that might be present.

While the reagents were mixed in the proportions specified in Table III, the actual compositions of the slags were not the same as the calculated compositions. Corrosion of the crucible and stirrer serves to dilute the slag, and a slight volatilization of litharge always occurs. The latter factor, however, was found to be of less importance than the first. The variations of the slags secured from the calculated compositions were not determined by analyses, nor were attempts made to estimate them closely. For the original purpose of this work it seemed sufficient to specify the reagents used and the slags that they would yield if undiluted. While it is recognized that the actual slags will contain somewhat more of silica and alumina and less of litharge than the calculated compositions, nevertheless the uncertainty introduced by neglecting this factor is in most cases within the limits of other experimental errors, which arise from conditions that are independent of this one.

The Distribution of Silver

In the first series of experiments slag No. 3 was employed. Charges were made to yield 175 g. of this slag. They were melted in pairs with the amounts of argentiferous litharge required to give the desired initial silver concentrations to the slags. Each pair of charges was brought to 837 deg. C., and a button of silver lead alloy weighing 25.0 g. was added to each crucible, after which the slags were stirred, poured and assayed, as has been described in a preceding paragraph.

The results obtained from eight fusions of slag No. 3 at 837 deg. C. are shown in Table IV.

TABLE IV.—DISTRIBUTION OF SILVER BETWEEN SLAO NO. 3 AND
LEAD AT 837 DEG. C.

a	b	c	d	e	f	g
0.0040	0.0051	24.95	5.063	20.3	3980	3980
0.0060	0.0049	25.00	5.058	20.2	4120	3980
0.0075	0.0101	24.90	1025	41.2	4080	3920
0.0120	0.0099	25.00	1024	41.0	4140	3980
0.0120	0.0143	25.00	1548	61.9	4330	4160
0.0140	0.0185	25.00	1548	61.9	4270	4110
0.0150	0.0198	24.90	2031	81.5	4120	3960
0.0250	0.0198	24.90	2034	81.6	4120	3960

Average corrected ratio of concentrations = 3980

Explanation of table:

a = mg. of silver per g. of slag before lead is added.

b = mg. of silver per g. of slag after stirring with lead.

c = g. of lead-silver alloy at end of experiment.
Added to each crucible was 25.0 g.

d = mg. of silver present in the alloy at the start.

d = mg. of silver present in the alloy at the start.
e = mg. of silver per g. of alloy at the end = d/c.
f = mg. of silver per g. of alloy / mg. of silver per g. of slag,
both at the end of the experiment = e/b.
g = corrected ratio of equilibrium concentrations as explained
below.

The concentration of the silver in the lead or metal phase at the end of the experiment was obtained by dividing the weight of silver originally employed by the weight of alloy remaining. On the other hand, the concentration of silver in the slag could not be so calculated, but had to be determined by assaying. Therefore not all of the silver present in the slag was recovered, the principal loss being that due to cupellation.

In the first experiments attempts were made to determine the cupellation losses and to apply appropriate corrections, by employing checks made up of proof silver and lead in amounts approximating those present in the assay buttons. But it was found that owing to the small amounts of silver present the agreement between checks was hardly close enough to warrant their use. The losses from carefully prepared checks cupelled under apparently identical conditions would vary from about 3 per cent to 6 per cent of the silver originally taken. From the results of thirty such checks it was found that, under the conditions of cupellation employed, an addition of 4 per cent to the weight of silver remaining after cupellation would provide as reliable a means of correcting for cupel losses as could be conveniently employed. This is, of course, the average correction, and its application to an individual result cannot be expected to invariably yield the true silver content of the lead button before cupellation. But the application of this correction to several results will yield an average corrected result that will approximate the truth. Therefore, the ratios of the concentrations of silver in the lead and silver in the slag, shown in column "f" of Table IV, have been divided by the factor 1.04 and entered in column "g" as corrected ratios. This produces the same result as if the slag assay values had been multiplied by this factor.

The results shown in Table IV prove conclusively that at constant temperature a definite distribution of silver between lead and slag will occur, the silver passing either from the slag to the lead or from the lead to the slag as may be necessary to establish the equilibrium. It is also shown that as the silver concentration in the lead increases its concentration in the slag, required to produce equilibrium, will increase in direct ratio. That is, the ratio of the equilibrium concentrations of silver in metallic lead and in a slag of given composition is a constant, at constant temperature. Thus it appears that this distribution possesses the characteristics of one in which the solute has the same molecular weight in both solvents. In this respect it resembles the succinic acid, ether, and water system mentioned above.

The limits of concentration of silver in the lead, shown in Table IV, were chosen because with lower concentrations the difficulty of obtaining exact assays of the slag is greatly increased; while with higher concentrations, it was anticipated that too great a variation of the composition might produce corresponding changes in the nature of the metal phase, and thus alter the characteristics of the equilibrium. In subsequent work a mean between these extremes was selected, and silver-lead alloys containing approximately 1 g. of silver in 25 g. of the alloy were used.

Slag No. 3 possesses very favorable properties, which allow experiments to be made over a greater range of temperature than is possible with any of the other slags. Its formation temperature and melting point are low, and at the low temperatures it is quite fluid without being excessively corrosive to the crucibles at the higher temperatures. The results of

further experiments to determine the distribution ratio of silver between this slag and lead are given in Table V. The details of the observed data and the methods of calculation having been shown in Table IV, only the figures essential to a clear presentation of the facts are given in the following tables.

Owing to the fact that the furnace in which the melts were made was wound with a nickel-chromium resistance alloy, it could not be used at temperatures above 1050 deg. C. without frequent renewals of the resistor. Consequently, the distribution ratios of Table V that correspond to the temperatures 1143 deg. and 1173 deg. C. were determined by a method which differs somewhat from the one already described.

For determinations at these temperatures a coke-fired muffle furnace was employed. Two crucibles and their charges were placed in the back of the muffle. In front of these were placed empty crucibles of the same size, which served to restrict the air circulation and to produce a very uniform temperature around the charged crucibles. Temperature measurements were made by sighting a Morse thermo gage through a small hole in the muffle door upon a crucible painted with ferric oxide, which stood in an inverted position

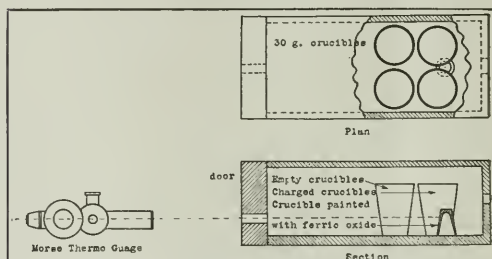


FIG. 2—ARRANGEMENT OF CRUCIBLES IN COKE-FIRED MUFFLE

directly between the two charged crucibles. Reference to Fig. 2 will make the arrangement clear.

All experiments performed on slags 1, 2, 4 and 5 were conducted in the electric furnace according to the first method described. Owing to the extreme

TABLE V.—THE DISTRIBUTION OF SILVER BETWEEN LEAD AND SLAG NO. 3 AT VARIOUS TEMPERATURES

Temp. C.	a	b	c	d	e	Average Ratio
780	0.0050	0.0064	41.1	6420	6130	
780	0.0075	0.0066	41.2	6240	6000	
780	0.0050	0.0064	41.2	6440	6190	
780	0.0075	0.0064	41.2	6440	6190	6140
837	See Table IV for complete data.....					3980
892	0.0150	0.0163	41.5	2550	2450	
892	0.0180	0.0159	41.3	2600	2500	
892	0.0150	0.0155	41.0	2640	2540	
892	0.0180	0.0155	41.0	2640	2540	2510
960	0.0180	0.0244	41.5	1700	1635	
960	0.0260	0.0242	41.5	1715	1650	
960	0.0180	0.0244	41.5	1700	1635	
960	0.0260	0.0244	41.6	1705	1640	1640
1045	0.0300	0.0370	41.6	1125	1080	
1045	0.0450	0.0390	41.6	1070	1030	
1045	0.0300	0.0358	41.1	1150	1110	
1045	0.0450	0.0370	41.1	1110	1070	
1045	0.0300	0.0400	41.3	1030	994	
1045	0.0450	0.0386	41.4	1070	1030	1050
1143	0.00	0.0555	36.5	658	634	
1143	5.25	0.0552	35.4	641	616	625
1173	0.00	0.0659	38.7	588	565	
1173	5.25	0.0654	37.4	572	550	558

Explanation of table:

a = mg. of silver per g. of slag before lead was added.
 b = mg. of silver per g. of slag after stirring with lead.
 c = mg. of silver per g. of lead-silver alloy at end of experiment.
 d = ratio of equilibrium concentrations = c/b.
 e = ratio of concentrations corrected for losses incurred during assay of slags.

fluidity of slags No. 1 and No. 2 and to their tendency to rapidly corrode the crucibles, experiments with them were attempted only at the lower temperatures. On the other hand, slags No. 4 and No. 5 could be worked with only at the more elevated temperatures, because of their high formation temperatures and high viscosities. As has been noted above, slag No. 3 possessed properties most favorable to investigation over a considerable range of temperature. Hence the experiments with it are more complete than in the case of any of the others. Results of experiments on slags 1, 2, 4 and 5 are collected in Table VI, wherein the letters at the heads of the columns have the same significance as in Table V.

One of the crucibles contained the reagents necessary to produce 175 g. of slag No. 3. The charge was allowed to fuse, and, when the formation of the slag was practically complete, 25 g. of a silver-lead alloy containing about 920 mg. of silver was dropped into the crucible. The alloy was added in the form of filings. The other crucible contained the same slag forming constituents as the first, but in addition there were present 28 g. of argentiferous litharge and enough argol to produce a 25 g. lead button. The silver present amounted to about 920 mg., and it had been originally added to the litharge in the form of a silver nitrate solution. The charge in the second crucible was allowed to fuse as if it were a regular assay. It is evident that in these two charges the initial conditions were not the same. In the first case the slag had no silver at the start, so silver passed from the lead to the slag after the addition of the alloy. In the second case all of the silver was present at the start as nitrate or oxide, from which condition it had to be reduced in order to alloy with the lead. Hence the lead had to remove some silver from the slag as it generally has to do in the ordinary assay.

After remaining in the furnace for about 70 minutes the crucibles were removed and samples of slag were decanted from the lead and assayed as usual. The lead buttons were allowed to freeze in the crucibles, after which they were broken out, weighed, and cupelled with checks to determine the amounts of silver present.

In applying this method the most uncertain factor is the temperature, the regulation of which is not so readily accomplished in the coke furnace as in the electric furnace. But by careful firing it was possible to secure temperatures so uniform that the thermogage reading indicated a rise in temperature of less

than 12 deg. C. during the last 30 min. of the heating. The temperatures specified correspond to the readings taken just before the muffle was opened to pour the crucibles.

The average ratios of the equilibrium concentrations given in Tables IV, V and VI have been plotted to scale with their corresponding temperatures in Fig. 3. In this figure there is also shown a curve representing probable values of the distribution ratio of silver between lead and pure litharge at various temperatures, the position of this curve having been calculated from the observed data by a method of extrapolation, which will be explained later.

TABLE VI.—THE DISTRIBUTION OF SILVER BETWEEN LEAD AND SLAGS NO. 1, 2, 4 AND 5, AT VARIOUS TEMPERATURES

Slag No.	Temp. C.	a	b	c	d	e	Average Ratio
1	837	0.0150	0.0193	42.8	2220	2140	
1	837	0.0200	0.0203	43.7	2150	2060	
1	837	0.0150	0.0199	42.7	2140	2060	
1	837	0.0200	0.0204	43.3	2120	2040	2050
1	892	0.0200	0.0291	43.5	1490	1430	
1	892	0.0400	0.0280	42.8	1530	1470	1450
2	837	0.0150	0.0159	41.5	2610	2510	
2	837	0.0250	0.0155	41.8	2700	2600	2555
2	892	0.0200	0.0240	42.0	1750	1680	
2	892	0.0350	0.0252	41.6	1650	1590	1635
2	960	0.0250	0.0375	43.2	1150	1110	
2	960	0.0500	0.0400	42.1	1050	1010	1060
4	892	0.0050	0.0100	41.0	4100	3940	
4	892	0.0150	0.0096	41.1	4290	4120	
4	892	0.0050	0.0104	40.8	3920	3770	
4	892	0.0150	0.0112	41.0	3660	3520	
4	892	0.0050	lost	...	...	...	
4	892	0.0150	0.0098	40.8	4160	4000	3870
4	960	0.0100	0.0147	41.0	2790	2680	
4	960	0.0200	0.0151	40.7	2700	2600	
4	960	0.0100	0.0150	41.4	2760	2650	
4	960	0.0200	0.0152	41.4	2720	2610	2635
4	1045	0.0200	0.0253	40.8	1580	1520	
4	1045	0.0400	0.0269	40.8	1520	1460	1490
5	960	0.0050	0.0098	41.1	4200	4040	
5	960	0.0150	0.0100	41.1	4110	3950	3995
5	1045	0.0150	0.0157	40.8	2600	2500	
5	1045	0.0250	0.0168	41.0	2440	2350	2425

For explanation of a, b, etc., see Table V.

The Effect of Temperature

The marked effect of temperature upon the ability of the slags to retain silver in the presence of metallic lead is well illustrated by the curves of Fig. 3. For example, at 800 deg. C. a gram of lead-silver alloy in contact with slag No. 3 will contain about 5200 times as much silver as will a gram of the slag; at 1150 deg. C. this ratio is only 600 to 1. Within a temperature range of 350 deg. the ability of the slag to retain silver in the presence of metallic lead experiences more than an eight-fold change. Changes in the concentration ratios with temperature in the case of the other slags are correspondingly great. In view of the great effect of temperature upon the distribution of silver between the metal and the slag it is evident that close regulation of the temperature during an experiment is essential, if reliable results are to be secured.

(To be concluded)

The National Association of Manufacturers held its annual convention at the Waldorf-Astoria, New York, on May 15, 16 and 17. About 500 delegates were present, representing 4000 industrial concerns throughout the country. It was declared that the wave of prosperity in this country is increasing rather than abating. A resolution was adopted that a plan of organization be formed, representative of as many industrial organizations as possible, which may agree on certain definite principles and may express its opinion with respect to government measures and policies.

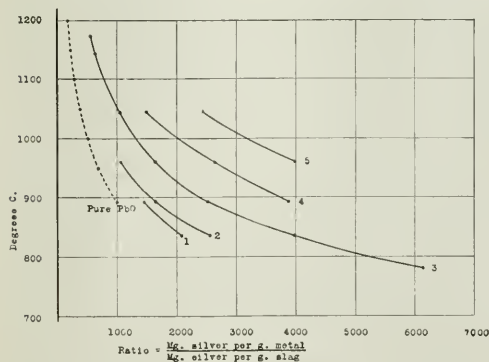


FIG. 3.—EQUILIBRIUM CONCENTRATION RATIOS OF SILVER IN SILVER-LEAD ALLOYS AND SLAGS AT VARIOUS TEMPERATURES

The Distribution of the Charge Column and of the Ascending Gas Column

BY J. E. JOHNSON, JR.

Granting that the foregoing articles have given a fair idea of the many actions which go on inside the furnace, and the fundamental laws by which they are limited and controlled, with methods for calculating the burden desired for each given case, it might be thought that the problems concerning the operation of the furnace were all solved. It would be nearer true to say that their solution was just begun.

The question on which the practical operation of the furnace depends more than any other is the distribution of the raw materials in the top of the furnace, and while far less important the question of distribution of the gas in the different zones of the furnace is a matter of great moment, the two being obviously interdependent to some extent.

We have discussed the first of these questions at some length in the article on filling the blast furnace, and the second in the article on mechanical principles. It may be as well to confess frankly at the beginning that it is far easier to handle these two questions from those points of view than it is from the complex one of operation.

As I have emphasized several times before, the prime desideratum is that each particle of the burden shall have a uniform exposure to gas and to heat in its journey down through the shaft and bosh into the hearth. The question is how to secure this condition.

Distribution and Control of the Gas Column

Leaving for the present the more difficult question of distributing the stock let us consider that of controlling the gas flow. This may be considered from two points of view: first, that of conditions in the lower part of the furnace within the range in which penetration is effective; second, the upper regions of the furnace, roughly speaking, the shaft.

THE DISTRIBUTION OF THE BLAST IN THE HEARTH AND BOSH

In the first region we have two factors of control. One is the penetration itself, the other the density or openness of the charge column in its different portions from the center outward. Reference to Figs. 1, 2 and 3, in the article on mechanical principles (issue of January 1, 1916, page 41) shows that the effect of improper penetration, whether too great or too small, is gradually smoothed out by time and flow until at a certain distance from the tuyeres the distribution of the gas is no different with bad penetration from what it is when good. Obviously the distance in which this levelling action occurs is important. The experimental difficulties in making determinations of this point would be vast, not to say insurmountable, we have therefore to guide us only our general knowledge of furnace operation.

I have often heard of attempts to control the action of the gas by penetration at levels far above the top of the bosh, but as far as my own observation goes I have reached the conclusion that the top of the bosh is about the limit of the height within which changes in the action of the furnace may be produced. We do know, however, that they can be produced up to this level because we know that we can regulate the tendency of the furnace to build or scour on the bosh even quite close to the top of the latter by altering the size and length of the tuyeres, and if a scaffold forms on the bosh we know that we can generally remove it by proper alteration of the penetration. On the other hand I have known of at least one case where a scaffold was formed

on the lower part of the bosh by excessive penetration, driving the gas column to the center of the furnace and allowing the bosh walls to remain so inactive that slag and other materials built on them so as almost to shut off the passage of the gas altogether.

It is important to notice in this connection that an action which is started by the gas itself may develop in such a way as to increase that action. Thus, if the gas is passing too much to the center and a scaffold begins to build on the walls just above the tuyeres its tendency is to throw the gas still more strongly to the center and thereby favor still further building on the walls, this condition continuing until the furnace can no longer operate, as in the case mentioned.

On the other hand I have already mentioned the case of a furnace with very deficient penetration in which the charge column built up like a cone in the center of the hearth and filled the latter up until there was nothing left except a narrow ring around the outside. In that case the formation of a "dead-man" in the center of the furnace naturally tended to throw the blast back more strongly against the walls and so to cut them away more actively, with the result that the lining of the hearth on this furnace was almost totally destroyed after a comparatively short campaign, and breakouts in consequence were numerous.

It is perhaps too broad a statement to say that improper penetration brings about conditions which tend to increase the very tendencies that produced them, and so continually get worse, but we may safely say that this is the result in many cases, and for this reason, as well as on its own account, correct penetration is of the utmost importance.

IRREGULAR PENETRATION

In all that has gone hitherto we have assumed that the penetration was alike at all the tuyeres. But this is unfortunately not true, and differences in the quantity of wind blown into the tuyeres in different sectors of the furnace have been responsible for some very unsatisfactory furnace work whose cause was to the last degree obscure and hard to find. In ordinary practice the hot blast main strikes the annular bustle pipe around the furnace on a truly radial line, and in that case if there is a reasonable length of straight main next the bustle pipe the blast naturally divides itself evenly around the two sides of the latter, and we have symmetry of distribution on each side of this principal diameter, but in regard to the diameter at right angles to it this is not the case. The velocity of the blast in the hot blast main is exceedingly high, and the surface friction being quite large the drop in pressure per unit of length is far greater than in most air piping, so that the pressure on the side next the inlet is on the average appreciably higher than that on the opposite side, and the pressure at the first two or three tuyeres next the inlet is considerably higher than those in the same semicircle but further from the inlet.

This condition in itself is bad and the remedy appears at first sight to be simple. We need only to increase the diameter of the bustle pipe until the pressure is virtually the same all around it. But to this there are two objections. First: the bustle pipe is enormously large and heavy even as now constructed for high velocities and would of course be correspondingly worse for lower ones. Second: the remedy under conditions which have prevailed at all plants until recently, and at most even yet, would be of short-lived benefit because the dust picked up by the blast out of the stoves is carried through the gas main and into the bustle pipe. Near the inlet the velocity is high enough to keep it moving, and instead of settling it is carried out the tuyeres, but

in the portions of the circle more remote from the entrance the velocity having become proportionately diminished, the dirt soon settles and gradually builds up in the pipe, reducing its area down to that at which the velocity is sufficient to prevent more dust from settling.

In some cases the conditions are even worse than this. The hot blast main is brought into the bustle pipe not on a radial line but eccentrically. This makes a sort of back-water of the region just back of the inlet (see Fig. 1) because the blast owing to its high velocity cannot turn the sharp corner so as to supply this region properly and therefore its blast supply, at least in part, has to travel all the way around the circumference of the bustle pipe. This, of course, greatly exaggerates the conditions described for the symmetrical arrangement, the region immediately in front of the inlet receives a decided over-supply of blast, and the region just behind it a correspondingly deficient one.

At least one case is on record in which certain furnaces having the hot main about three feet off the center of the bustle pipe (not enough to be visible to the naked eye without close observation) ran fairly well on foundry iron but very unsatisfactorily on basic iron. It seemed impossible to keep the sulphur low enough when the silicon was within the proper limits. Finally the trouble was traced to the asymmetrical arrangement

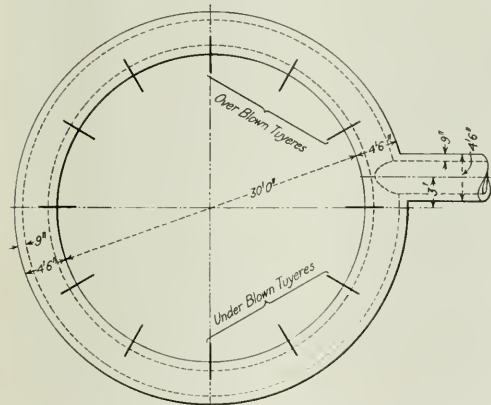


FIG. 1. EFFECT OF HOT MAIN ENTERING BUSTLE PIPE UNSYMMETRICALLY

and the tuyeres just in front of the inlet were changed to a smaller size so as to prevent the higher pressure of the blast in this portion of the bustle pipe from driving an excess of wind through these tuyeres. This cured the trouble absolutely and the furnace thereafter gave entirely satisfactory results on basic iron.

Since the realization of the conditions brought about by this case much more attention has been paid to this subject and now in some cases it is the practice to use smaller tuyeres next to the inlet even on furnaces with symmetrical bustle pipe, and this practice is probably well founded. It would seem legitimate also to increase the tuyeres on the far side to a corresponding extent, but this is commonly not done.

Just what is the mechanism by which the action of the furnace is upset under these conditions we do not know. Two or three theories could be advanced, some of which would be exactly opposite to others. But we do know that the prime condition for proper furnace work is absolute and complete uniformity of conditions on all sides of the furnace, and that such a condition as this, violating fundamentally that requirement, must produce bad results.

I incline to the belief that the action in such a case is somewhat as follows: We know to a certainty that if the furnace as a whole be blown to its proper capacity, the region receiving the excess of air must be over-blown. This means that the stock is allowed less time than it should have for complete reduction and this in turn probably means a scouring slag which leads to high sulphur. The more rapid rate of driving in this sector leads to a more rapid descent of the charge in that sector, and owing to the greater mobility of its lumpy portion this means that the lumps tend to be drawn toward this zone of the furnace. It is as though the layers of charge which should normally be horizontal were tilted down on this side so that the lumps tend to travel this way. These require more time for their complete reduction than do the fines, therefore tend to exaggerate the raw condition of the iron produced in this sector, and being more open and permeable to the gas they tend to increase the velocity of the gas in this sector and therefore to exaggerate the conditions which originally started the irregularity.

In other words, we have here again a case in which the tendency probably is for the results of a certain condition to react on the causes of that condition so as to make it worse, the evil being thus self-intensifying. It will be seen therefore that it is not only important to have the areas of all the tuyeres correct to give the proper penetration but it is important to have the total area so distributed among the different tuyeres as to compel an equal quantity of blast to enter the furnace in each sector.

EFFECT OF STOCK DISTRIBUTION ON GAS FLOW IN BOSH

Turning now to the second factor in the control of the gas column in the lower portion of the furnace we have to consider the varying density of the charge column. This is a subject concerning which we know but little. I shall presently describe a case in which a dense impervious core was produced by the filling, and this undoubtedly descended into the bosh. But rodding tests at the tuyeres did not show any conclusive evidence of deficient penetration at that level, and rather drastic variations of tuyere diameters to try the effect of increasing penetration upon the dense core did not yield any results of value. This seems curious; it would be foolish to try to give a reason for so obscure and complex a phenomenon, but it may be suggested that the dense core in that portion of the charge in the shaft being made up almost entirely of ore and flux, as we know it to have been constituted, was melted by the expenditure of much extra coke somewhere up in the bosh and ran down into the hearth. This then would leave the coke free to fill the space vacated and would produce the condition of comparatively uniform penetration which we found.

Claims have often been made as to the effect on the bosh walls of changes in the filling, that they built up with certain kinds of filling and scoured off with others, etc. I have never had any experience in which I could identify these conditions myself, but they may exist. My own feeling is that penetration is the predominate factor in gas distribution up to the top of the bosh, and above that stock distribution is the controlling, almost the sole factor.

THE EFFECT OF STOCK DISTRIBUTION ON GAS FLOW IN THE SHAFT

In the article on filling the furnace we have seen the necessity for distribution symmetrically about two or more equally spaced axes, and this symmetry must not be only quantitative but qualitative. It is not sufficient to have the same total amount of material in each sector of the furnace, we must have equal quantities of *each*

of the raw materials in the charge, and further than this we must have as far as possible equal quantities of each size of the different kinds of raw materials.

I have endeavored to emphasize this so strongly in the chapter mentioned that perhaps no additional stress need be laid upon this point here. But these requirements alone are not enough, the distribution of the different sizes of materials in the proper position radially is as important as is a symmetrical distribution circumferentially.

THE EFFECT OF THE SIZE OF THE BELL

The effect of the wall in increasing the voids in the material adjacent to it was also pointed out in the article on filling, and we know from the considerations there given that at least a considerable portion of the fine material should be placed against the walls by the charging operation. In regard to the quantitative effect of the further factors which control in this important and complicated matter we have no information whatever. We know that a bell large in proportion to the stock line will distribute most of the fine material against the walls, and we have already seen that this is desirable up to a certain point, but if the bell be made too large the effect on furnace work is not to improve it further, but to make it distinctly worse. We do not know precisely why this is. We may well imagine, however, that the placing of too great a proportion of the fine material immediately adjacent to the wall cuts off the currents of gas to so great an extent that that portion of the charge is not kept active, and this leads as we know by experience to building on the walls, consequently to formation of incipient scaffolds, and all the evils which they bring in their train.

Of course, if we make the bell too small then the fine material is deposited too close to the center of the furnace, the lumpy and more open portions of the charge roll to the walls, by which their natural voids are increased, as we have seen in a previous article, almost 100 per cent, and the result can only be that the gas rushes violently up the sides of the furnace, leaving a column of more or less dead material up the center which is deprived of its proper proportion of the reducing action of the gas and so descends into the hearth in a raw condition, while on the other hand the extreme rapidity of action produced next the walls by the excessive gas currents makes the lumpy portion of the charge travel too fast, which has two bad effects. First: the outer portion of the column descending more rapidly than the inner tends to increase what might be called the reversed-crater action next the walls with the result of drawing a still greater proportion of the lumpy material to that region, and so increasing the objectionable action which gives rise to these conditions. Second: the lumpier portions of the charge need more time for their complete reduction than do the finer ones, hence the larger lumps, in spite of the excess gas to which they are exposed, tend to reach the hearth improperly reduced because not allowed sufficient time for complete reduction.

It becomes plain, therefore, that there is a satisfactory explanation for the fact, which we know so well by experience, that to do good work the stock distribution must not only be symmetrical, but the size of the bell must be such as to put the proper proportions of fine and coarse material in their proper radial positions.

DIFFICULTIES OF EXPERIMENTS ON MODELS

It might be thought that it would be simple to determine experimentally what size of bell and other top arrangements would give these desired conditions, and such attempts have been made on scales of varying sizes dozens of times. They are open to two objections.

First, it is very difficult to duplicate in an experimental way either full size or on reduced scale the actual conditions which prevail at the top of the furnace. To begin with we have no means of causing the regular and uniform settling of the charges as we deposit them in our experimental apparatus, and if we do not produce uniform settling we cause a cratering action in one or another portion of the top surface which is likely to distort or destroy the correctness of the results obtained with subsequent charges. There are, of course, many other operating and practical difficulties in the way of such experiments, not the least of which, if they be full size, is the expense.

Second, granting that we can determine correctly with an experimental apparatus the results that will be obtained with any given design, how are we to select the one which will produce the best results on the furnace?

On one occasion the general superintendent of a certain plant declared to a visiting furnace man his intention of constructing a full size model of his furnace top and experimenting on it with all kinds of distribution, and then at the end of the experiments selecting the one which he liked best. The visiting furnace man asked how he knew that the furnace would like best the system that he liked best. No answer was forthcoming, and from the nature of the case it is almost obvious that none could be. The laws affecting symmetry of stock distribution, etc., we understand quite well; they are fundamental. But having that foundation, there remains a great superstructure of details to be built, for the design of which we have not, and seem likely never to have, any simple or inductive method; nothing but the slow and tedious process of trial and error, varying one detail at a time, keeping all other conditions constant, is sufficient for the solution of so difficult a problem.

Add to this the almost infinite difficulty of keeping all the other conditions constant under such complex conditions, and it becomes easier to understand why we have as yet so little knowledge even of the empirical kind to guide us in these matters. General experience is sufficient to give us a fair working start and reasonably good results. Anything beyond that must be obtained by each individual furnace man to suit his own conditions.

THE EFFECT OF SIZING ON MIXED MATERIAL

This is a subject to which too little attention has been paid. Its importance was first pointed out, so far as known to me, in a paper by Mr. Frank Firmstone.

The reasoning is very simple. If we take a quantity of spheres, all of the same size, we can quite easily figure the percentage of voids between them, as has already been done in an earlier article, and this is a perfectly definite mathematical proportion. But if we started off with, say, 3-in. spheres, we could insert into the larger interstices of these smaller spheres, say 1 in. in diameter, and into the interstices then remaining still smaller ones, say $\frac{1}{4}$ in., and into the interstices still remaining smaller ones, say $\frac{1}{16}$ in., and so on down. The size to which we should descend in the individual case is controlled by the size of the raw materials with which we have to deal. Now supposing that we have a mass made up of heterogeneous spheres with all the interstices filled with the smallest size of spheres we have available. Suppose that we put the whole mass over screens which separate it into their original uniform sizes? Each of these sizes would contain, of course, the fixed mathematical proportion of voids above given, no matter how small the spheres might be, and the gross volume of the sized material would be far larger than

the volume of the mixed mass of heterogeneous spheres, in which obviously the percentage of voids would only be a small fraction of what it was in each of the sized varieties.

What is accurately and mathematically true of spheres is true in a general way of irregular material, particularly if that irregular material be of a uniform kind, and have, therefore, an approximately similar shape, irrespective of its size, which is roughly the case with the different kinds of raw material, so that for any considerable mass of a given irregular material the same general laws hold as for the mass of spheres.

Remembering now that one of our fundamental laws for proper operation of the furnace is that each portion of the charge column must be exposed to the same quantity of gas, and considering the enormous effect of permeability on the passage of the gas currents, the practical effect of this general law becomes obvious. If we wish to make the charge column more permeable in any given portion we must have recourse to sizing of some kind, and if we desire to make the charge column as a whole more permeable sizing of all the fine portions of the raw materials is our only recourse.

Working along this line I made some experiments several years ago whose results are indicative of the great effect which may be produced in this way. We made a heavy wooden box containing 1 cu. yd., and filled this with the crushed hard ore of the Birmingham district, crushed to go through a 3-in. ring. We then cut this cubic yard of ore into three sizes, over one screen, and over and through another. The first attempt gave portions of very different sizes. On the second attempt we used screens of $\frac{7}{8}$ -in. and $\frac{5}{32}$ -in. mesh, and these two screens cut the whole mass into three almost equal portions.

The specific gravity of the solid ore was determined in the laboratory, and from the weight of the original cubic yard we could easily determine what its volume unbroken would have been. The difference between this and the cubic yard gave its voids in the mixed condition. After screening, the volume of each of the three portions was determined by putting it back in the cubic yard box, leveling its top carefully, and measuring the depth. [This is very important, because if the volume of the portions be determined in a smaller box, the wall effect, that is, the increase in the voids next to the walls, for the reason already pointed out, is so great that the results are entirely distorted and worthless.]

By adding together the volume of the sized portions we obtained the volume of the original cubic yard in its sized condition, and deducting from this its calculated volume in the solid condition we obtained the total voids in the sized ore. This was increased 45 per cent over the voids in the original mixed ore. The detailed results are shown in Table I. The effect of such an increase in the percentage of voids on the permeability of the charge could not fail to be very marked. Unfortunately, we were unable to carry out any experiments on the use of such sized ore on the furnace itself, though the conditions under which it operated gave every reason to hope for substantial benefits.

In more recent years John N. Reese has made many sizing tests of Lake Superior ores entirely independent of the work done by me, and has found that precisely the same laws hold in all fine Mesabi ores as in the coarse hard ores of the South. The difficulties, however, of sizing in the case of such material as Mesabi ore are almost insuperable from the practical point of view, and it seems unlikely that we shall ever see a practical application of these laws in the case of such exceedingly fine material.

There is, however, one practical application of these

Table I.—Data of Screening Test on Birmingham Hard Ore

Specific gravity (laboratory).....	3.45	
Coarse through 3-in. ring.....		
Over ¾-in. mesh (made from No. 9 B & S wire, 1 in. center to center).....		
Middlings.....		
Under ¾-in. mesh over 5/32-in. mesh (No. 5 B & S wire ¼ in. center to center).....		
Fines.....		
Under 5/32-in. mesh.....		
Weight of 1 cu. yd., actual measure of crushed unscreened ore.....		
Weight of 1 cu. yd., solid ore (from specific gravity).....	3852.5 lb.	
Weight of 3852.5 lb. ore if solid.....	805.0 lb.	
Volume of 3852.5 lb. ore if solid.....	17.92 cu. ft.	
Voids in one cu. yd., mixed crushed ore.....	9.08	
	27.00	
Voids in per cent of total volume.....	33.7	
<i>After Screening.</i>		
	Coarse Middling Fines	
Weight in per cent of total.....	33.0 32.9 34.1	
Weight in pounds.....	1271.5 1267.0 1314.0	
Cubic feet of solid ore.....	5.91 5.90 6.11	
Measured volume of crushed screened ore, cubic feet.....	10.25 10.92 9.92	
Total volume.....		31.09
Volume of ore solid as above.....		17.92
Voids in crushed screened ore, cu. ft.....		13.17
Per cent of voids.....	42.4 46.0 38.4	
Average per cent voids in screened ore = 42.4.		
Volume of voids per given weight of ore, 13.17 cu. ft. in screened ore as against 9.08 cu. ft. in unscreened, or an increase of 45 per cent.		
This last is evidently the important consideration for practical purposes.		

This last is evidently the important consideration for practical purposes.

principles which I believe could be made much more frequently than it now is, and that is to abstain from mixing ores of different sizes with the idea that the coarser would loosen up the finer. The only result which this can possibly have is to cause the finer to obstruct the coarser without benefiting itself, and if ores of different degrees of fineness are to be charged in the same furnace they should be charged separately, not even in the same round, if this can possibly be avoided, because the more they are mixed the worse the results must necessarily be. There may be one case in which it is justifiable to violate this rule. When the main portion of the charge consists of a fine sandy ore, and a minor portion of the charge is of a lumpy or plastic nature, the latter portion may be charged first separately, so as to make a blanket over the top of the coke and prevent the fine ore from running down through the fuel. The loss of porosity in this case is more than compensated by preventing contact between fine ore and fuel, but I wish to reiterate my conviction that, generally speaking, where two ores of different coarseness are to be charged the more widely separated they can be the better will be the results on the furnace. If I had two furnaces and a total ore supply made up of one-half very fine and one-half coarse, I should be very much tempted to use all the coarse in one furnace and all the fine in the other. Perhaps alternate charges of each kind would be as good, but certainly either of these would give vastly better results than mixing the fine and coarse in the same charge.

THE SIZE OF THE COKE CHARGE

This is a point of much importance, and in this, as in so much else that concerns the filling of the furnace, we have only empirical knowledge to guide us. Mr. E. A. Uehling pointed out several years ago that the effect of the layer of ore on the gas rising through it was an oxidizing one, while the effect of the layer of coke immediately above was a reducing one, and that as we desired the maximum of reduction by gas, it was very important not to have the fuel and ore charged in a mixture, but to keep them in separate layers, and that, moreover, the effect of the separation was greater the thicker were the individual layers. This is simply another phase of the fact which I have already attempted to emphasize, that the more points of contact of ore with coke the greater the solution loss, and the poorer the economy, and in principle this is entirely correct.

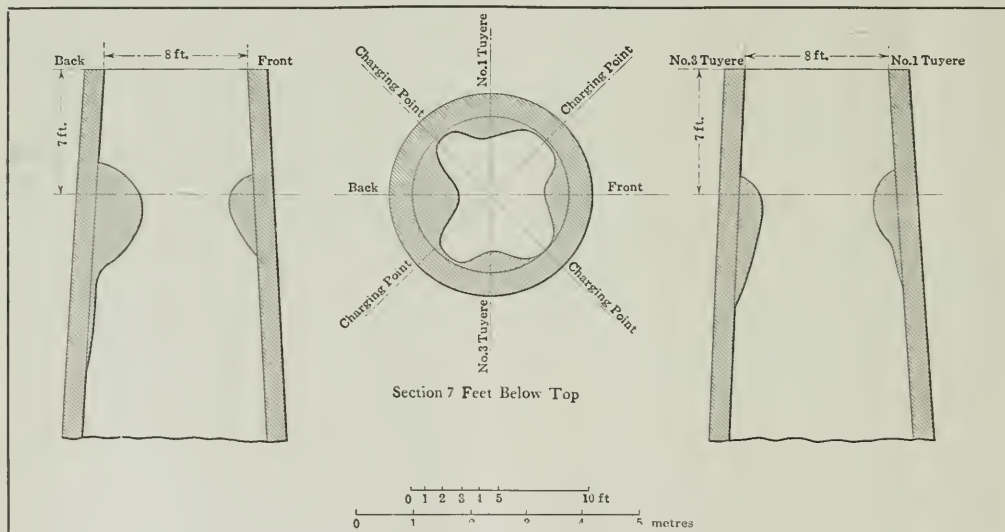
There is obviously a limit, however, since there must be a certain intimacy of mixture between the ore and the coke which is to perform the final reduction upon it in the hearth, and it is presumably this factor which sets a limit to the size of the fuel charge which we can use. That there is such a limit has been determined by the experience of many furnace men. My own experience covers one such case whose results were unmistakable. In order to obtain more symmetrical filling at a charcoal furnace with a very small stock line diameter, and using very large barrows, I wished to use four barrows at a charge instead of two. A first attempt was not successful because the top as it stood was not adapted to correct dumping at four points, but on a subsequent blast, having redesigned the top so as to permit absolutely symmetrical dumping at four points, I started the furnace off with a four-barrow charge. After a week or so of operation in which the fuel consumption remained far higher than it should, I became convinced that the thickness of the charge layers might have something to do with it and changed to a two-barrow charge, obtaining symmetry by alternating the dumping positions on each alternate charge. The result was immediate. The fuel consumption of the furnace at once dropped 5 or 6 per cent, and its work became more sat-

isfactory for reasons of simplicity and easy construction by a single outlet on one side communicating directly with the downcomer.

Many furnace men have felt that this construction was open to criticism because the path of the gases originating immediately under the gas outlet is shorter and therefore easier than the path of the gases on the opposite side, and in less degree at intermediate points, and they have felt that this produced a lack of symmetry in the gas current which was likely to affect adversely the working of the furnace. Many furnaces, however, ran successfully with this construction, and other furnace men came to believe that this was a theoretical point of no practical importance.

As the rate of driving has increased, however, the effect of this difference in resistance has become more marked, and an increasing number of furnace men have come to believe that the single gas outlet was wrong, not only in principle but in practice. Fortunately this is a subject on which we have evidence of such overwhelming weight that the matter need never again be considered open for discussion once the evidence is considered.

The brown ores of Virginia and Tennessee contain small quantities of zinc, which is vaporized by the heat



FIGS. 2, 3 AND 4. ZINC RING (FIRMSTONE)

isfactory in all respects. From such data as are available it seems that the average thickness of the coke charge in a 22 by 90-ft. furnace is about 2 ft., and this appears to be more or less established practice with furnaces of this size on Lake Superior ores. For furnaces of smaller size it is probable that the thickness of the fuel bed for best results remains about the same and that, therefore, the weight of the proper coke charge diminishes in proportion to the diminished area (not diameter) of the stock line.

THE EFFECT OF THE LOCATION OF THE GAS OUTLET ON THE DISTRIBUTION OF THE GAS CURRENTS THROUGH THE FURNACE

In the article on filling it has been pointed out that the old practice was to use the center out-take for the gas, thus securing perfect symmetry for the gas current from all portions of the furnace. This was suc-

cessful for reasons of simplicity and easy construction by a single outlet on one side communicating directly with the downcomer. Many furnace men have felt that this construction was open to criticism because the path of the gases originating immediately under the gas outlet is shorter and therefore easier than the path of the gases on the opposite side, and in less degree at intermediate points, and they have felt that this produced a lack of symmetry in the gas current which was likely to affect adversely the working of the furnace. Many furnaces, however, ran successfully with this construction, and other furnace men came to believe that this was a theoretical point of no practical importance. As the rate of driving has increased, however, the effect of this difference in resistance has become more marked, and an increasing number of furnace men have come to believe that the single gas outlet was wrong, not only in principle but in practice. Fortunately this is a subject on which we have evidence of such overwhelming weight that the matter need never again be considered open for discussion once the evidence is considered.

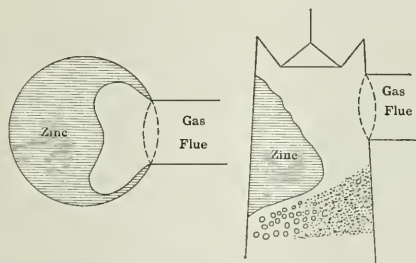
Mr. H. Firmstone in a paper before the American Institute of Mining Engineers in 1876 described the action of this material in the furnace at Longdale, which was equipped with the center out-take and double bell. His drawings of the shape of the zinc ring formed,

found on blowing out, made from very careful measurements, are reproduced in Figs. 2, 3 and 4. The approximate symmetry of the formation about two axes at right angles is obvious. The thin places in the ring are immediately under the dumping points, because most of the fines of the charge remaining at those points obstructed the gas currents, while half way between the dumping points were the coarser portions of the charge which permitted a more active gas circulation and consequently the deposit of more zinc oxide.

These results were confirmed by all the subsequent experience at these furnaces. The symmetry was not always so marked, but was in general greater in proportion as the furnace was more regular, but any irregularity was what might be called self-intensifying, because a greater growth of zinc ring meant a greater distortion of the charge and more obstruction of the fines, which were crowded over and could not roll back under the obstructing zinc, while the coarse could and did do so, and thereby produced a more open charge condition under the obstruction and so brought a greater portion of the gas current to that section of the furnace, and thereby promoted a still greater growth of zinc formation.

This effect was so serious and the detrimental action on the regularity and fuel economy of the furnace was so great that it became the custom to shut the furnace down for about forty-eight hours every six months and cut off the zinc ring with long steel bars, sledging them from the operating platform. Incidentally this job was including the removal and replacement of the top apparatus, of such severity and difficulty as to make one wish at least during those periods that he had chosen another occupation.

About twenty years later W. W. Taylor described in the *Iron Trade Review* the growth of zinc "ring" in a furnace filled with a single bell and provided with a single gas outlet on one side, this furnace being very hard-driven for its size. Mr. Taylor's drawings of this zinc formation are reproduced in Figs. 5 and 6. It will



FIGS. 5 AND 6. THE EFFECT OF A SINGLE LATERAL GAS OUTLET ON GAS FLOW AS SHOWN BY ZINC OXIDE DEPOSIT (TAYLOR)

be seen that the zinc formation started at a point exactly opposite to the downcorner opening, presumably because the smaller gas current, due to the longer path the gas on that side had to travel, permitted a greater cooling effect. The stock was forced to flow over the nose of the zinc formation toward the center of the furnace. The fines stayed where they fell in that position. The coarse rolled back to the wall underneath the zinc formation and induced a more rapid flow of gas to that side. Greater cooling followed the more rapid downward travel of the lumpy material and more zinc followed the greater upward flow of gas. Consequently, the deposit of zinc was bound to grow here and to work its way down the furnace as the cooling effect of the

coarse material descended further and further, until the lower end of the zinc formation reached down almost to the top of the bosh.

The furnace was working almost entirely on this side, and the other side was presumably almost dead. I have seen the same thing at Longdale in a less degree on several occasions. The zinc formation descended to the lowest level in the furnace underneath those points where the obstruction to the descending charge had been the greatest. Of course from this reasoning it is evident that once the zinc formation were started in this way with the single gas outlet it had no recourse but to grow increasingly worse. This, however, is not the most important lesson to be learned from this most instructive bit of furnace history; it is that the original zinc formation would never have occurred in the way it did in the first place if there had not been a decided lack of symmetry in the gas current due to the longer path on the side opposite to the single gas outlet, and I believe that all experienced furnace men will agree with me that the above constitutes an absolute proof that an unsymmetrical gas outlet is bound to lead to irregular distribution of the gas column relative to the charge column, and that while its effects are probably not so strongly self-intensifying as when zinc is present, nevertheless it offers possibilities of trouble, to avoid which no reasonable expense in construction should be spared.

THE EFFECT OF THE TAPPING HOLE AND CINDER NOTCH LOCATION ON THE GAS COLUMN

It has been contended by some furnace men that the drawing effect of removing the liquid contents of the furnace hearth in one direction or another toward the tapping hole or the cinder notch affected the gas distribution, and that this effect could be offset by a corresponding lack of symmetry in the location of the gas outlets, but I have never seen anything in my own experience to confirm this contention, nor have I been able to discover any reasoning which would lead to such a conclusion. The iron and slag are withdrawn from the furnace when the blast is on, and therefore when the conditions in the hearth and bosh are normal, which means when there is a state of violent activity throughout all those regions. Remembering that the (solid) coke in the bosh is so intermixed with slag and gas as to constitute the whole mass a liquid, it is difficult to see why it should not retain an approximately horizontal surface throughout all portions of these regions. Of course, the liquid concerned is to some extent viscous, and the tendency is for it to descend more rapidly in those portions where the flow lines are the shortest, and so during such periods there might be some effect on the distribution of the gas current, but it would not seem likely that this should be very marked.

On the other hand, the erosive action of the liquid flow must not be forgotten, and it is easily conceivable that a tendency to build up on the hearth or bosh walls might be prevented by the scouring of the liquid flow in the immediate vicinity of the tapping hole and cinder notch, while in regions remote from these points, there being no such scouring action, building up to some extent might occur and so in time produce a lack of symmetry sufficient to be important. For these reasons it is probably better not to have the cinder notch and the tapping hole too close together, and if physical conditions permit, a wise arrangement would be to have two cinder notches and to space these and the tapping hole at 120 deg. apart, using the cinder notches alternately. This, however, represents an ideal condition toward which we may aspire rather than a practical construction which we can ordinarily obtain.

THE EFFECT OF THE SIZE AND THE UNIFORMITY OF MATERIALS ON DISTRIBUTION

This is a subject which has had too little consideration in connection with the general subject of stock distribution, and the penalties which have been paid for failure to observe it have been both numerous and so severe in many cases as to be almost fatal to the success of the plant. It seems not generally to have been recognized that it is necessary not only to place the same amount of material in each sector of the shaft, but that the size of that material is of equal importance with the amount, and it is perfectly conceivable that careful tests might show the most absolutely uniform size of heaps on the bell (or on the stock line if examination inside the furnace be made before blowing in), but at the same time the distribution might be horrible because one section might be made up of lumps open and easily pervious to the gas, while all the others were made up of fine or even plastic material.

Of course, in regard to the coke this is only true to a limited extent, since with reasonably uniform handling the coke from one operation should be of reasonably uniform size, and this is a point which can under ordinarily favorable conditions be watched, and precautions taken to prevent variations in the coke, or if they must occur to insure that at least all one kind of coke shall not go to one side of the furnace and another kind to the other side.

But with the ore, particularly in the Lake Ore district, the conditions are very different. A certain percentage of old-range ores is generally, but not always, charged, and a much larger percentage, sometimes practically the whole charge, is made up of Mesabites. The ores from this range differ greatly from one another in degree, some of them being of almost impalpable fineness, and others containing a noticeable proportion of lumps, but as a whole these ores are of a sandy structure; that is to say, fine, relatively uniform and granular, while the great majority of old-range ores are either hard and lumpy, or else plastic, very much like ordinary clay except in color, the clay sometimes being interspersed with lumps, but the ores virtually never sandy.

It is obvious that the action of these ores in passing through the filling mechanism and through the furnace itself must be very different. The plasticity of some of them is so great that they will build up on almost any surface they touch, while others are almost as sharp and clean as crushed gravel. Some are so plastic that they will hold puddles of water for days, and, of course, when baked by the heat of the furnace tend to burn into hard, irregular lumps, while the sandy Mesabites, when dried by the heat of the furnace and agitated by the ascending gas currents, become almost as active as a liquid, and run almost as freely. The permeability of some of these ores to the gas current is obviously many times greater than that of others, while even with one kind of ore, if there be both fine and coarse produced in mining and crushing, the inevitable differentiation in size which takes place in dumping will divide a mass of this ore into two obviously different portions, one consisting of nearly all lumps, with very little fine, the other of a much greater portion of the fine with very little lumps. The difference in the permeability of these to the gas current is almost as different as if they were different kinds of ore.

If we start out, therefore, with a single kind of lump ore, the very action of dumping will produce a segregation, and we shall deliver two very different kinds of material into different portions of the furnace, of which one will probably contain two or three times as large a percentage of lumps as the other, with a correspondingly high percentage of voids, permitting free passage of the

gas, while the closely-packed fines in the other portion tend to obstruct the gas flow to a much greater degree. These conditions, of course, are repeated charge after charge, and in consequence we have perhaps all the lumps going down one side of the furnace, while all the fines and perhaps much more than half of all the material charged go down the other side.

This brings about a condition in the furnace which tends progressively to grow worse, because the freer travel of the gas through the coarse or open material causes all reaction on that side to be more rapid, and therefore causes the stock on that side to settle faster than on the side which receives the fines. This, of course, produces more or less of a crater in the top surface of the stock, and as the large lumps always travel the farthest, this means that the larger pieces to an increasing degree go into this crater while the fines stay around its rim. This increased segregation of the lumps causes still greater openness of the charge column at this point, and this in turn causes a still more rapid gas flow on this side with corresponding retardation on the other. The blast furnace being an apparatus which accommodates itself marvelously to unfavorable circumstances may not show by its output or fuel consumption the severity of the treatment to which it is being subjected, or only to a minor degree, though this is not generally the case, since bad filling is generally accompanied by extremely high fuel consumption and output poor in both quality and quantity. Moreover, such a condition can have only one result on the duration of the furnace campaign, no matter what its results may be on coke consumption and tonnage, and in this respect the results of such filling cannot be concealed for a very long time.

Its inevitable effect is to scour out the lining, not only by the predominance of the lumps, with their greater abrasive action on one side and their greater velocity, but also by the velocity of the ascending gas with its burden of abrasive dust. The lining is soon cut through, a fact which manifests itself by a hot spot on the shell within a few months or even within a few weeks of the opening of the campaign.

An excellent description and full data of such a case may be found in the paper of David Baker before the American Institute of Mining Engineers, Vol. XXXV, giving the results of the first campaign of the blast furnaces at Sydney, Nova Scotia, which were skip-filled and supplied with a burden of all lump ore.

The campaigns were not a matter of years, but scarcely one of months before the segregation, due to the use of the ordinary double bell top, without any attempt at circumferential distribution, had scoured through the lining to the shell in a rather narrow vertical zone, with the resulting necessity of blowing out and relining the furnaces, at an expense of many thousands of dollars.

Where fine ores are used exclusively it is obvious that such great segregation of the ore cannot take place, there being no coarse material upon which the segregating tendencies can operate. Consequently, with fine ores, if the quantity distributed to each sector of the furnace is the same, the results are not so serious and may be fairly satisfactory, because the absence of a difference in size eliminates the necessity for one of the fundamental conditions, viz., that in each sector the same proportions of lumps and fines, as well as the sum total of material, shall be charged.

It is a matter of painful recollection to those in the business during the period of the introduction of Mesabite ores that the furnace practice was notoriously unsatisfactory, particularly in the matter of life of linings, although at that time it was considered an achievement

to use 50 per cent of fine Mesabi, the remaining 50 per cent being Old Range ores, much of it of a lumpy or partly lumpy structure, whereas now 80 to 90 per cent Mesabi is common.

It has seemed to me probable that these Old Range ores, which were kept on to temper the admittedly bad effects of the fine Mesabis, may have been responsible for many of the lining troubles which were so frequent during that period. It is true that fine ores in themselves are very bad for reasons which I shall subsequently point out, but it is also true that if the burden is to be improved by mixing lumps with it, these lumps must be charged in such a way that an equal percentage of lumps and fines must go to every sector of the furnace. If they do not, the benefit due to the presence of the lumps, which is, I think, not nearly so much the opening up of the charge as has been believed, does not compensate for the fearfully bad effects of a segregation of lumps in one vertical segment of the furnace.

In confirmation of this it is certainly true that as the percentage of the objectionable Mesabi ores has risen, and that of the desirable lumpy ores has fallen, furnace practice generally has improved instead of growing worse, particularly in relation to life of linings. This is undoubtedly the product of many factors, and it may be a more or less academic question to discuss what those factors were, but I am firmly convinced that lumps not properly charged will not benefit a burden of fine ore, but will produce an additional detrimental action of their own, and I would rather run a furnace on an all fine ore burden entirely without lumps than I would on a mixture of lumps and fines if I could not absolutely guarantee the proper distribution of the lumps.

While matters are, as just stated, much improved now from what they were twelve or fifteen years ago, the question of stock distribution is still a very live one among the best informed furnace men, and the development of the furnace top is not yet at a standstill.

More than one furnace manager has told me that after the most painstaking experiments he has found it impossible to obtain a distribution with a plain double bell top which was good for more than one condition of weather, ore, etc. It is this conviction which has brought about the introduction of the rotating top or rotating distribution.

EXPERIENCE WITH THE REVOLVING DOUBLE-BELL TYPE OF TOP

A very unusual experience with furnace distribution a few years ago has imbued me with certain ideas in regard to stock distribution which are by no means held by all furnace men, so that I shall give the facts on which my conclusions are based.

At the time stated I was in charge of a plant of three furnaces, all equipped with the revolving double-bell type of top, the receiving hopper under the skips being a cone almost exactly as illustrated in Fig. 7. These furnaces, which were in the South, were operated on a

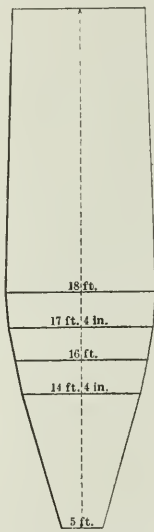


FIG. 7. BLAST-FURNACE OUTLINE

coke of only moderately good quality, and on an ore consisting entirely of lumps as mined, but containing a considerable quantity of fine as received on account of unsatisfactory methods of crushing, and their performance was exceedingly unsatisfactory. A fair tonnage could only be obtained from them at the expense of a high fuel consumption, a high blast pressure, and an exceedingly limited life of lining. The revolving top was fitted with automatic electrical recording pens, and it was the special duty of the burden clerk to check over these records to see that the skips were dumped in the proper sequence, that the receiving hopper was rotated to the proper angle, that the bells were manipulated after the proper number of skip loads, and that in general all details of charging were correctly carried out.

Within a few weeks after blowing in these furnaces would show a hot spot on the shell some 20 or 30 ft. above the mantle, not in any one position circumferentially around the shell, showing channeling, but indifferently at any point, and spreading from that point around until the furnace shell was hot in this zone most of the way around. The last thirteen or fourteen months of blasts, averaging fifteen or sixteen months, were made with a water spray on the shell to keep it cool. At the end of this period the furnace could no longer be operated and was blown out and relined completely.

As one of the furnaces was approaching the time set for it to be blown out for repairs its shell failed at a point some 40 ft. below the top, and a section some 8 ft. high by 12 long swung out like a barn door, letting all the material in the furnace run out down to that level. I took charge within a day or two afterward, and as there had been discussion as to the distribution in these furnaces it was decided to shovel out the stock remaining in the furnace, not from the bottom as is customary, but from the top, so that by cutting vertical faces across the stock in various directions we could obtain an accurate idea of the distribution which prevailed in actual operation, this being an opportunity which would not ordinarily arise once in a lifetime, the furnace having been in full operation up to the time of the shell failure, then immediately stopped and watered down.

The condition which this investigation revealed was astounding, and was one under which no one would have believed that a furnace could operate at all. The brick being all gone at the zone in question the furnace was about 24 ft. in diameter; the outside 4 ft. of this was taken up by a ring of coke entirely unmixed with ore and limestone, while the center was made up exclusively of ore and limestone with only an occasional piece of coke.

The assistant superintendent, Mr. W. L. Klutz, who had been at the plant for several years under the previous administration, had maintained for some time that the furnaces were working with a core in the center, and had much valid evidence to support this view, but even he was not prepared for a confirmation of his opinion to this extent.

It seemed obvious that the bell was too small for the stock line, that the fine material dropping from the edge fell in a heap in the center, or at best in a small ring around the center, while the coke being larger traveled further and lodged entirely against the walls. Obviously, then, the thing to do was to reduce the size of the stock line or increase the size of the bell. To make sure we did both, and careful inspection of the stock surface when the furnace was being filled preparatory to lighting, made by going in under the bell, showed practically all the fines against the walls and nothing but large lumps of coke in the center. Air could be felt drawing up through the center freely, whereas no draft could be felt against the walls.

I felt convinced that we should obtain a different result and the furnace was blown in with high hopes, but after being in operation for six weeks without doing any better work in output or coke consumption than on the previous blast, and finally developing a small hot spot on the shell, we became convinced that we had not solved the problem.

Mr. Klutetz then suggested that the difference between that furnace and some other furnaces in the district, which were giving much more satisfactory results under precisely similar conditions, was that our stock distribution was in uniform rings while theirs was in heaps on the main bell, and he suggested that we so modify our top to secure this effect at least in part, which we could do without great expense.

The spout which we could put in was limited, and we were not sure that it would be long enough to secure approximately even distribution when opposite to the skip and when directly under it, but it seemed that nothing could be worse than the present conditions, so the change was made. No change of ore, coke, burden, blast, heat, or any other factor of furnace operation was made. At the end of the first day no change in the working of the furnace was visible. At the end of the second day the furnace without notice came up on 8 per cent silicon iron. It then became a matter of increasing the burden rapidly enough to bring the furnace down to normal foundry iron without danger of chilling it if the change suddenly went the other way. No such untoward event occurred, however, and at the end of five days from the time the change was made the furnace had gone from a daily production of 223 tons, with a coke consumption of 3300 lb., to a daily production of 285 tons and a coke consumption of 2750 lb.

The same change was made on another furnace which was supposed to be so nearly worn out as to be good for only about another month, but its work improved so greatly with the change that it was kept in for seven or eight months longer. As a result of this successful experiment the top of the next furnace which went out of blast was redesigned so as to convert it into the spout type of top somewhat similar to the Brown, but designed to secure the proper distribution both radially and circumferentially. This furnace ended only recently the campaign on which this modified top was installed, having run about forty-five months instead of the fifteen, which was formerly standard practice for those furnaces, and after making a record for tonnage and coke consumption such as no furnace at that plant had ever approached.

In view of these facts it is perhaps not surprising that in my judgment distribution in heaps on the bell is to be preferred to a distribution in rings altogether apart from the question of symmetry. Every furnace in that district fitted with the same type of top had given results precisely similar to ours, running with high fuel consumption, low output, high blast pressure, and short life. Other furnaces with the same type of top in other districts using very different types of ores had experiences so similar that a description of theirs might have been taken for ours. At the same time it must be admitted that in those districts where the ore is nearly all fine the contrast between ring distribution and heap distribution is much less marked in operation than it is in districts where the greater portion of the ore burden consists of lumps.

This experience agrees in a general way with experiences along a similar line at the time of the introduction of the closed-top furnace. I have been informed by Mr. Frank Firmstone [in private communication] that during the régime of the open top it had been considered good practice to spread the stock as smoothly

and uniformly over the top as possible. But when the introduction of the closed top brought about the use of the filling barrow, which necessarily dumped in heaps on the bell, the furnace work instantly and very generally improved. Why this should be so has never been made clear. I have never seen any explanation of the fact, which in itself is not very widely known. The only explanation that I have been able to make even tentatively is that when the ore is all dumped uniformly in rings the percentage of voids in it is much smaller than that which occurs in the lump portion when segregation of the lumps takes place. When the ore is dumped in heaps on the bell the tendency is for the lumps to segregate to some extent not only at the bottom of the hopper, but also along the sides of the piles made by dumping, and as the sides of these piles are practically radial this causes radial lines of more open stock to descend through the furnace, and thereby open up to the action of the gas the fines which may tend to gather there, thus preventing the formation of a column of more or less "dead" stock down through the center of the furnace.

That such a column may be formed, the facts I have already cited amply prove, and that by descending more slowly in consequence of its impenetrability to the gas this column tends to perpetuate itself by affording a lodgment for the fine material of the charge, while forcing the coarse to roll to the periphery is also true, and that the effect of dumping in heaps is to cause segregation of fine and lump, and thereby cause vertical planes of greater openness at the edges of the individual heaps is also true to some extent. But whether the comparatively slight change in the penetrability of the central column so produced is sufficient to cause the vast changes in the working of the furnace which I have seen at this plant and others cannot be considered as proven. Anyone who will advance a logical and satisfactory explanation of this action will lay the blast furnace profession under a lasting debt of gratitude.

Engineers in Preparedness Parade

Engineers played an important part in the impressive preparedness parade held in New York City on Saturday, May 13. The parade lasted approximately 12 hours and was composed of about 125,000 citizens representing a great number of professions. The engineers were led by the Naval Consulting Board, followed by the other engineers; mechanical, chemical, mining, civil, electrical, etc. There were between 200 and 250 in the chemical engineers' division and an equal number in the mining engineers' division.

Problems in Petroleum Industry

Dr. Raymond F. Bacon, director of the Mellon Institute of Industrial Research, lectured before the New York Section of the Society of Chemical Industry on the evening of May 19 on some problems in the petroleum industry in a very interesting and able manner, urging the need of more extended research. From the industrialist's viewpoint the great problem is flexibility in refining in order that only such products as are in special demand at the time may be produced, as at present gasoline and lubricating oils. The research was outlined on processes for the dehydration and desulfurization of crude oils and for the depolymerization of heavy oils, and especially on problems encountered in the chemical treatment of petroleum products and some present-day technical difficulties in refinery engineering. Petroleum will, like natural gas, form the basis of a chemical products industry which will be as distinct as the coal-tar industry of to-day.

The Extraction of Gasoline from Natural Gas by Absorption Methods*

BY G. A. BURRELL,¹ P. M. BIDDISON,² G. G. OBERFELL³

This paper deals with a method of extracting gasoline from natural gas by absorbing the gasoline in oil and subsequently separating the gasoline from the oil by distillation. The process is quite different from compression and condensation methods that have been used for a number of years for extracting gasoline from casing-head natural gas and has not heretofore been described in the literature.

The extraction of gasoline from casing-head natural gas by compression and condensation methods has assumed the proportions in this country of a large and lucrative industry, and placed in the market in the year 1914 about 43,000,000 gal. of gasoline. In addition there was used in marketing this casing-head gasoline at many plants an equivalent quantity of naphtha with which the casing-head gasoline was blended, thereby utilizing for automobile fuel and other purposes a very large quantity of naphtha that otherwise would have been unsuited for these purposes. A depression in the price of gasoline part of that year kept the production down to a certain extent. The increase for the year 1914 over 1913 was about 18,000,000 gal. For the year 1915 the production should be well in excess of 75,000,000 gal., and in 1916 well over 100,000,000 gal. The quantity of casing-head natural gas treated in the year 1914 by compression and condensation methods amounted to about 17,000,000,000 cu. ft. The average yield of gasoline was 2.43 gal. per 1000 cu. ft. This casing-head natural gas represents gas that formerly went largely to waste, hence the process represented a distinct and important step in the conservation of the natural resources of this country.

A description of the methods employed in the manufacture of casing-head gasoline and a discussion of the tests to determine whether sufficient gasoline is present in a given type of natural gas to warrant the installation of an extracting plant is contained in Bulletin 88 of the Bureau of Mines.⁴

By the compression and condensation method of treating natural gas, only casing-head natural gases, or so-called "wet" gases could be treated, and in order to make the operation profitable natural gases that contain less than $\frac{3}{4}$ gal. of gasoline per 1000 cu. ft. are usually not utilized. Hence there has been exempted not only a large amount of casing-head natural gas, probably more than one-half the available supply, but also the enormous and much larger amount of so-called "dry" natural gas that is used in cities and other places for domestic, factory, and other uses. The quantity of this kind of natural gas consumed in 1914 amounted to 591,000,000,000 cu. ft.⁵

By absorption methods much of the so-called "dry" natural gas can be treated. The method consists essentially in bringing the natural gas in contact with some kind of a heavier oil than gasoline, or in using a low-grade naphtha, and letting the absorbents absorb the gasoline from the natural gas, and either separating the extracted gasoline from the oil by distillation, or if a naphtha is used, say about 50 deg. Baumé specific

gravity, simply letting this naphtha absorb as much of the natural gas gasoline as it will, thereby increasing the volume and also producing a blend that is intermediate in specific gravity between natural gas gasoline and the naphtha used as an absorbent.

PRODUCTION OF NATURAL GAS IN 1913 AND 1914

Table I gives the production and value of natural gas⁶ for the years 1913 and 1914. This table shows a production of 591,866,733,000 cu. ft. of natural gas for the year 1914, an increase of about 10,000,000,000 over 1913.

TABLE I—QUANTITY AND VALUE OF NATURAL GAS PRODUCED IN THE UNITED STATES IN 1913 AND 1914, BY STATES

State	1913			1914		
	Quantity (Cubic Feet)	Cents per M. Cubic Feet	Value	Quantity (Cubic Feet)	Cents per M. Cubic Feet	Value
West Virginia	245,453,985	13.92	\$34,164,850	238,740,162	14.87	\$35,515,329
Pennsylvania	118,800,269	18.25	21,695,845	108,494,387	18.80	20,401,295
Ohio	50,612,211	20.79	10,521,930	68,270,174	21.48	14,667,790
Oklahoma	75,017,668	9.91	7,436,380	78,167,414	10.30	8,050,639
Kansas	22,884,547	14.37	3,288,394	22,627,507	14.76	3,340,025
New York	8,515,257	28.50	2,425,633	8,935,187	29.10	2,600,352
Louisiana	26,652,626	7.95	2,119,948	26,774,695	8.32	2,227,999
Alabama						
Texas	12,159,755	17.05	2,073,823	13,433,639	18.38	2,469,770
California	11,034,597	17.07	1,883,540	17,828,928	16.33	2,910,784
Indiana	2,920,314	25.52	843,407	2,579,675	29.28	755,407
Illinois	4,707,128	12.04	574,015	5,947,412	12.51	743,575
Kentucky	1,821,526	27.93	509,846	1,421,818	34.52	490,875
Arkansas						
Colorado						
Wyoming	1,106,374	24.35	269,421	962,998	22.23	214,103
South Dakota						
North Dakota	66,492	48.87	31,166	60,781	44.78	27,220
Missouri	20,865	32.57	6,795	18,083	29.41	5,318
Michigan	1,805	77.84	1,405	2,042	10.61	1,442
Tennessee	2,400	25.00	600	1,200	25.00	300
Iowa	120	100.00	120	200	100.00	200

All of this gas will not be available for the absorption of gasoline from it, but the largest portion of it will be available. Almost all of the natural gas in the United States contains higher members of the paraffin series of hydrocarbons than methane. The ordinary combustion analysis of natural gas only shows the two predominating paraffin hydrocarbons, usually methane and ethane.⁶ The authors have never tested a natural gas that showed methane and ethane that did not contain in addition the higher members of the paraffin series of hydrocarbons when an additional test was made for these constituents. The latter comprise propane, butanes, pentanes, hexanes, etc. The latter two comprise most of the gasoline that is obtained by the absorption method.

These so-called "ethane" gases predominate among the natural gases of the country, undoubtedly to the extent of more than 500,000,000,000 cu. ft. used per year. For instance, all the natural gas used in Pittsburgh, Buffalo, Columbus, Cincinnati, Cleveland, Louisville and hundreds of other towns contains ethane.⁷ The same is true of natural gas produced in Oklahoma, Kansas, California, Texas and other States.

Some natural gases that contain methane as the only paraffin hydrocarbon are found in Louisiana, in the Caddo Fields, at a few places in Oklahoma, in the Murrysfield sand, Pennsylvania and at a few other places. These methane gases are the only ones that do not carry gasoline vapors. It may happen in a new well, where the pressure is very high, that not enough of the gasoline is carried by the natural gas to warrant the in-

*A paper read before the Natural Gas Association of America, Pittsburgh, Pa., May 15, 1916. Published with permission of Director of Bureau of Mines.

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⁴Mineral resources of the United States, U. S. Geological Survey, part 2, page 800, 1914, J. D. Northrop.

⁵Burrell, G. A.; Seibert, F. M., and Oberfell, G. G. The Condensation of Gasoline from Natural Gas, Bulletin 88, Bureau of Mines.

⁶Loc. cit., page 753.

⁷Northrup, John D. The Production of Natural Gas in 1914. Mineral Resources of the United States, 1914, part 2, page 751, U. S. Geological Survey.

⁸Burrell, G. A., and Seibert, F. M., The Sampling and Examination of Mine and Natural Gases. Bulletin 42, Bureau of Mines.

⁹Burrell, G. A., and Oberfell, G. G. The Composition of the Natural Gas Used in 25 Cities in the United States. Technical Paper 119, Bureau of Mines.

stallation of a plant to extract gasoline by the absorption process, but the most of the natural gas produced in this country undoubtedly can be treated at the present time.

If one assumes that one pint of gasoline can be obtained per 1000 cu. ft. of gas, there will be extracted 500,000,000 pints of gasoline from 500,000,000,000 cu. ft. of gas or about 60,000,000 gal. of gasoline per year. If one assumes two pints per 1000 cu. ft. then the total becomes 120,000,000 gal. per year. Probably 75,000,000 gal. would be a conservative estimate that can be obtained by treating the natural gas in this country at the present time. In the case of some of the so-called "dry" natural gas that the author tested, three pints of gasoline per 1000 cu. ft. were obtained. If one assumes that gasoline has a value of \$0.20 per gallon, then the total value of the gasoline becomes \$15,000,000 per year. At \$0.25 per gallon the sum becomes about \$19,000,000 per year.

This amount is about 20 per cent of the total value of the natural gas used in 1914 and probably about $7\frac{1}{2}$ per cent of the total quantity of gasoline consumed in 1914.

CONSUMPTION OF GASOLINE

During the year 1909 the quantity of gasoline consumed amounted to about 11,000,000 barrels. In 1914 the amount consumed had increased to 18,000,000 barrels, and it is estimated that the consumption in 1916 will be about 38,000,000 barrels of 42 gal. each or about 1,600,000,000 gal.

CONDENSATION OF GASOLINE IN PIPE LINE

Gasoline condensing in trunk lines is a constant source of annoyance and expense, because of its action on the rubber rings used in the patent pipe couplings, which are now universally used on all large pipe lines in place of the old-style socket and thread "collars."

It softens and decomposes the rubbers until they weaken and give way causing a "blow out," that is, the pipe line will part, causing the gas to escape into the air.

Repairing "blow outs" at all hours of the night is a large item of expense, besides the amount of gas lost in that manner is very great. The expense and annoyance frequently attached to the breaking of a gas line and escape of gas is shown by the recent experience of one of the large natural gas companies.

A report was received at the main office that the pressure on a certain line was falling at the rate of 30 lb. per square inch per hour, although the compression station reported everything normal there. This condition indicated a break in the line and men were immediately dispatched to patrol the line, and locate the difficulty, which was found about midnight. Twenty-six men were used the balance of the night and the next day in order to repair the line.

During this time the pressure had to be raised 70 lb. at the compressing station, and the factory service on the line discontinued.

One company informed the authors that the cost of rubber for couplings used in the pipe lines that transported 100,000,000,000 cu. ft. in 10 years through an 18-in. pipe line for a distance of 35 miles was not less than \$16,000.

This was for the rubber alone and did not include the cost of placing the couplings or other expense.

Thus it would seem that a method for removing gasoline from natural gas, thereby preventing the solvent effect of the gasoline on rubber pipe-line couplings becomes valuable for the latter reason, in addition to the fact that a valuable fuel is recovered for sale.

The Development of the General Process of Passing Natural Gases Through Oils or Naptha for the Extraction of Gasoline

As in the case of the casing-head gasoline process, the absorption process of extracting gasoline from natural gas has assumed industrial importance as the demand for gasoline increased. The idea follows closely the process of extracting benzole, toluol, and other vapors from gases made by destructively distilling coal. In this process the gases are caused to flow at about atmospheric pressure counter current to a stream of wash oil, a petroleum distillate as so-called "straw" oil or "mineral seal" oil or a coal tar distillate such as creosote oil. Absorbing towers in which this is accomplished are 50 to 75 ft. high and about 10 to 15 ft. in diameter. After the benzole and toluol have been scrubbed from the gas, the charged oil is sent to steam stills where the benzole and toluol are extracted. The process is continuous in that the absorbent oil is used over and over again.

The process has been used for many years in Germany and to a very large extent during 1915 and 1916 in the United States. Many types of absorbers and steam stills and different conditions of temperature and pressure were employed before a standard procedure was evolved. The difference between the process of extracting gasoline from natural gas and extracting benzole and toluol from coke-oven gases is that with the natural gas the absorption is conducted at high pressure. This is an economic necessity because the natural gas at present being treated by the absorption process exists at this high pressure, and cannot be profitably treated any other way. The transportation system must not be disturbed.

There might also be mentioned a process in vogue for a number of years past, and practised at some refineries of subjecting uncondensed gas and petroleum vapors from stills to absorption in naphtha, thereby increasing the gasoline yield considerably.

English patent No. 30,229, issued to Albrecht Von Groeling of Vienna, Austria, Dec. 24, 1909, covers a process for "improvements in or relating to the utilization of natural gases or petroleum distillation gases." The claims follow:

(1) A process for the utilization of natural gases or of petroleum distillation gases, consisting in treating the gases at an adjustable increase pressure and adjustably reduced temperature, by quantities determined beforehand, of an absorption medium, for instance of heavy benzine, the unabsorbed gases being then condensed by the use of high pressure and low temperature.

(2) An apparatus for use in carrying out the process set forth in Claim 1, in which the gas is treated, in a series of absorption apparatus arranged one behind another, at an adjustably varying increased pressure and adjustably varying reduced temperature, with the absorption medium, so that said absorption medium can circulate through the various absorbers, and the heat absorbed during the expansion of the compressed gases is withdrawn directly from the absorption medium for the purpose of cooling the latter.

(3) A process of the kind set forth in Claim 1, in which the gases utilized are first washed at an ordinary temperature and normal pressure with "heavy benzine."

(4) A process of the kind set forth in Claim 1, in which the natural gases escaping from a bore-hole, or petroleum distillation gases are first heavily compressed, then cooled and finally washed, in the state of exceedingly fine division, with cooled liquid benzine or the like, for the purpose of separating portions of the

gas that can be condensed, both the cooling of the benzine required for the washing, and the cooling of the gas utilized after the compression, being effected with the expanding gases escaping from the absorption column, the gas being finally condensed by the use of high pressure and low temperature.

(5) An apparatus for use in carrying out the process set forth in Claim 1 or 4, comprising a column several meters high, filled with benzine or the like, into the bottom portion of which the compressed cooled natural gases enter in a state of exceedingly fine division, the upper portion of the column being provided with an expansion valve through which the washed expanded gases pass downwards through an expansion coil or the like, through the washing liquid, for the purpose of cooling the same, and then proceed to the cooling.

(6) A process of the kind set forth in Claim 1 for utilizing natural gases or petroleum distillation gases by fractional condensation or absorption, in which the absorption medium is obtained by the preliminary condensation of the gas to be utilized, which is submitted to the gases still non-condensed, the cooling required for the condensation or absorption being obtained by the expansion of compressed gases or by evaporation of already condensed products under a relieved pressure, the gas being finally condensed by the use of high pressure and low temperature.

U. S. Patent No. 989,927, applied for in 1906 and issued April 18, 1911, to Geo. M. Saybolt specifies: Claim (1) that natural gas of the kind supplied to cities be subjected at pressures not less than 30 lb. per square inch to a naphtha absorbing menstuum and by the aid of the same under high pressure, effecting the separation in industrial quantity from said gas of a natural gas naphtha, liquid at atmospheric pressure and temperature, and applicable to the uses of petroleum naphtha of similar volatility substantially as described.

Claim (2) The process of obtaining naphtha from combustible gas of natural origin and underground source of the kind supplied by means of wells and pipe lines to the cities for consumption therein, which process consists in subjecting such gas in the requisite large amount on the way from its underground sources to its places of consumption and under a high pressure, not less than 30 lb. per square inch above atmospheric pressure, to a naphtha absorbing menstuum especially petroleum or hydrocarbon oil as specified, and by the aid of the same under said high pressure effecting the separation in industrial quantity from said gas, of a natural gas naphtha liquid at atmospheric pressure and temperature and applicable to the uses of petroleum naphtha of similar volatility, and then recovering the naphtha in liquid form from said menstuum by distillation under a low pressure, not more than about atmospheric pressure, substantially as described.

U. S. Patent No. 1,165,458, issued to John Snee, Dec. 28, 1915, specifies a means of providing for the retention of lighter or more volatile oils contained in the product of oil wells, gas wells and gas wells that produce both oil and gas. The claims follow:

1. The method herein described consisting in discharging all of the liquid and gaseous hydrocarbon products of an oil well into a liquid and gas container, and absorbing the gaseous hydrocarbons which accumulate within the container above the surface of the liquid.

2. The method herein described consisting in discharging all of the liquid and gaseous hydrocarbon products of an oil well into a liquid and gas container beneath the fluid level of the latter, and removing and absorbing the gaseous hydrocarbons released from the liquid within the container.

3. The method herein described consisting in dis-

charging all of the oil from an oil well into an oil and gas container, passing the gaseous products of the well into the oil thus discharged beneath the surface of the latter, and removing and absorbing the gaseous products released from the surface of the oil.

U. S. Patent No. 1,107,803 issued Aug. 18, 1914, to H. Koppers specifies that to extract naphtha from natural gas the latter is passed under pressure through a solvent oil in a cast-iron bell washer which is relieved of pressure by placing it within a wrought-iron casing through which gas passes.

To the authors' knowledge the first large-scale installation for extracting gasoline from natural gas was placed at Hastings, W. Va., by the Hope Natural Gas

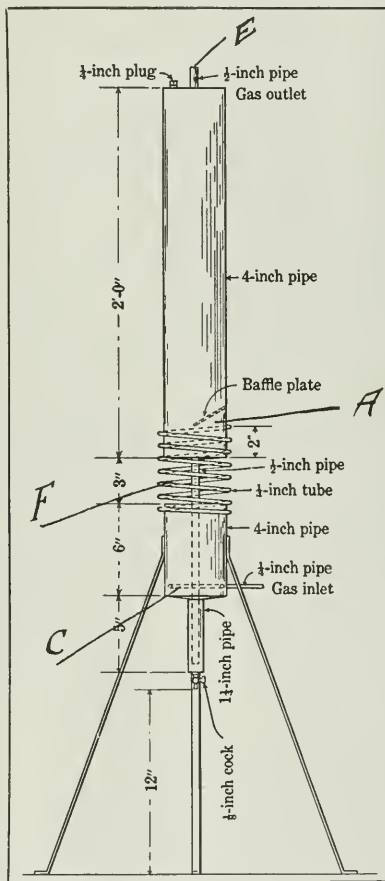


FIG. 1—SMALL ABSORBER FOR TESTING NATURAL GAS FOR GASOLINE CONTENT

Company of Pittsburgh, Pa. The plant was put in operation in 1913 as a result of the Saybolt experiments. The process consists in causing the natural gas to bubble up through mineral seal oil, the latter being then sent to steam still for the separation of the gasoline and the absorbent oil being used over and over again. The gas is passed through the absorbing oil at the high pressure of the line. The hot oil from the stills is cooled in a double-pipe cooler or exchanger by the cold oil en route to still and further cooled by passing through pipes upon which running water falls.

The general process, except for the utilization of the

gas under high pressure, is identical with the process of absorbing benzol and toluol vapors from coke-oven gases.

TESTING NATURAL GAS FOR GASOLINE CONTENT

In addition to laboratory tests whereby gasoline was frozen out of the natural gas the authors tested natural gas on a small scale with the absorber shown in Fig. 1.

It is built on the principle of a laboratory gas-washing bottle of the Friedrich type.

This absorber was made of iron pipe and thoroughly welded.

It is about 3 ft. high, and the two main barrels, A and B, were made of 4-in. pipe. The gas entering, bubbles up through the absorbing oil at *C* and passes through the coil of pipe *F*, and into the part *A* and out at *E*.

After the oil contained in the absorber had absorbed all of the gasoline that was desired, a portion of it was withdrawn and subjected to distillation to obtain the gasoline, which was measured and the yield of gasoline per 1000 cu. ft. of natural gas thus determined. This small absorber was designed to show the maximum yield of gasoline possible to obtain.

The process of extracting gasoline from natural gas by passing the latter through oil, simply consists in the solution of the gasoline in the absorbent. In passing natural gas with its gasoline vapor through an absorbent, there will occur a point when a particular oil will not take up any more gasoline. The authors determined that in the case of mineral seal oil this saturation amounted to 28 per cent, as regards tests they conducted.

In conducting the test natural gas was passed through mineral seal oil, using the smaller absorber shown in Fig. 1, until no more gasoline was found to be absorbed by the oil.

By a percentage saturation of 28 is meant that the amount of gasoline absorbed was 28 per cent of the final total volume of gasoline and oil.

But in the practical work of absorbing gasoline from

natural gas, the saturation percentage of the gasoline in the oil cannot be carried that far. It was found from actual tests that when the saturation of the gasoline exceeded 4 per cent, some of the gasoline in the natural gas was passing through the oil unabsorbed, *i.e.*, the extraction was not complete. As a saturation percentage of 4 per cent was exceeded more and more gasoline was absorbed, of course, from the natural gas" but at the same time an increasingly small amount of gasoline appeared in the exit gases.

This small amount was always less than the amount absorbed until a saturation of 28 per cent was reached, when the amount absorbed was equal to the amount given off, *i.e.*, from now on a condition of equilibrium was reached.

Therefore in all tests made both on the small absorbers and on the larger experimental plants a close tab was kept on the saturation percentage of the gasoline in the absorbent.

Two different oils were used as the absorbing medium in extracting gasoline from the natural gas in conjunction with those tests in which steam distillation was used to finally separate the gasoline from the absorbent. These oils were petroleum distillates.

Their characteristics as determined by E. W. Dean, petroleum chemist of the Bureau of Mines, are given in Table II.

TABLE 11—MINERAL SEAL

Flash point (Pensky-Martin closed apparatus).....	135° C., 275° F.
Burning point (Pensky-Martin open apparatus).....	160° C., 311° F.
Specific gravity (water=1).....	0.850

Upon distillation the first drop appeared at 225 deg. C. (405 deg. Fahr.) and 6.2 per cent distilled up to 275 deg. C. (527 deg. Fahr.).

STRAW OIL	
Flash point.....	183° C., 361° F
Burning point.....	208° C., 416° F
Specific gravity (water = 1).....	0.851

First drop distilled at 250 deg. C. (482 deg. Fahr.) and began to distill in quantity at 275 deg. C. (527 deg. Fahr.).

¹⁰This would occur up to 28 per cent saturation.

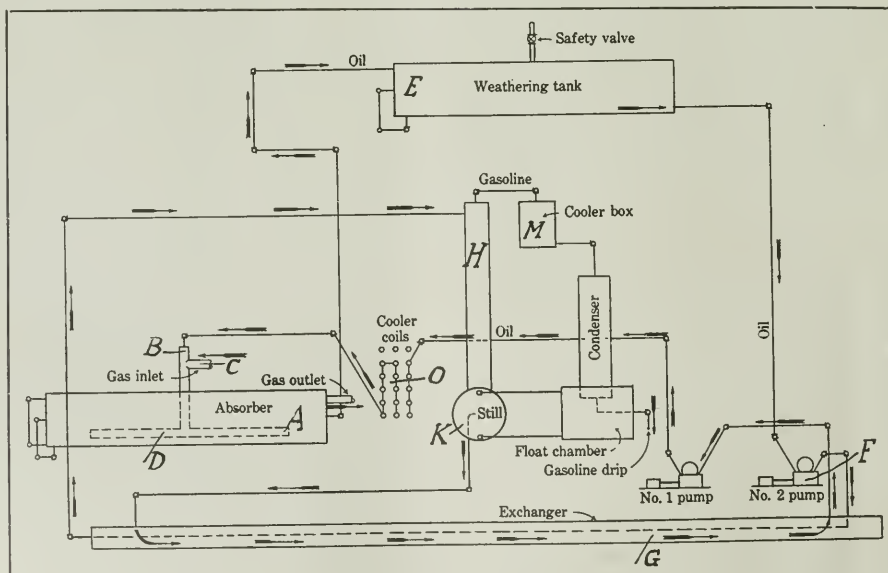


FIG. 2—PLANT FOR ABSORBING GASOLINE FROM NATURAL GAS

Description of Experimental Plants Using Mineral Seal Oil and Steam Distillation

While the tests were under way, using the small-scale experimental plant shown in Fig. 1, tests on a much larger scale were made with the plant shown in Fig. 2. This plant was capable of continuous operation in that natural gas was continuously passed through the absorbing oil and the latter after leaving the absorbers, charged with gasoline, was pumped to the steam still where the gasoline was removed and the oil pumped back to the absorbers to receive another charge of gasoline. This plant had a capacity of from 15,000 to 30,000 cu. ft. per hour.

A diagrammatic view of the plant is shown in Fig. 2.

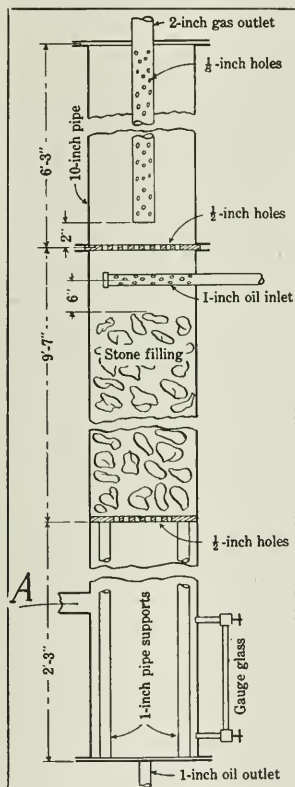


FIG. 3—TOWER ABSORBER

The gas enters the absorbing tank at *C* and the oil enters at *B*. Together they pass into the T pipe *D* and pass from there through many small holes into the oil contained in the absorber. The gas bubbling up through is stripped of its gasoline by absorption in the oil and passes out of the absorber as shown and goes on its way to the cities and other places for consumption.

The oil charged with gasoline passes first to the weathering tank *E*, where the lighter portions of the gasoline are released through the safety valve. Next the oil enters the pump *F* and is pumped through the heat exchanger *G* and from there into the rock tower *H* of the steam still *K*. Live steam enters this still and distills the gasoline from the oil. The cooler *M* is provided to separate the water (condensed steam) from the gasoline. The gasoline is condensed in the condenser and flows out of the system at the gasoline drip.

The hot oil after having been freed of its gasoline is passed through the heat exchanger *G* (thereby heating the oil passing to the still) and from No. 1 pump is forced through the water coils *O*, upon which running water drops. The cooled oil then passes into the absorber *A* to receive another charge of gasoline. The operation is continuous, the oil being used over and over again.

In addition to the type of absorber shown in Fig. 2, several other types of absorbers were used. The most efficient was a vertical or tower absorber shown in Fig. 3. Oil enters as shown and drops onto and through a column of stones of about the size of a fist. Gas enters at *A* near the base of the tower and flows counter current to the oil and out of the gas pipe at the top of the column.

YIELD OF GASOLINE USING THE SMALL ABSORBER SHOWN IN FIG. 1 AND THE PLANT SHOWN IN FIG. 2

In Table III are shown data of tests, using the "plant" shown in Fig. 2. In test 1 the tower absorber was used and in test 2 the absorber shown connected with the plant. The tower absorber gives the best results.

In Table IV are shown some results using the small absorber, shown in Fig. 1 and at different pressures. Pressure conditions made a decided difference. The

TABLE III—TESTS OF NATURAL GAS USING DIFFERENT ABSORBERS

Test No.	TOWER ABSORBER, MARCH 3, 1916				No. 4 ABSORBER, MARCH 3, 1916			
	1				2			
Time	8	9	10	11	8	9	10	11
Pressure at inlet to absorber, lbs. per sq. in.	222	215	211	211	225	220	216	215
Pressure on still, lbs. per sq. in.	3	3	2 75	2 75	3	3	2 75	2 75
Temperature of oil, deg. F. (in absorber)	55	64	66	68	66	66	66	68
Temperature of oil outlet, still deg. F.	207	210	208	209	212	212	212	210
Temperature of vapor outlet cooler, deg. F.	142	170	164	176	170	172	184	172
Temperature of cooling water, deg. F.	52	52	52	52	52	52	52	52
Temperature of still, deg. F.	215	216	216	216	216	216	216	215
Temperature of oil outlet absorber, deg. F.	54	58	60	62	60	58	60	68
Sp. gr. absorbing oil inlet to absorber, deg. B.	34 2	33 7	33 5	34 4	34 5	34 5	34 5	34 4
Sp. gr. absorbing oil outlet from absorber, deg. B.	36 4	36 2	36 0	35 8	35 0	35 2	35 0	34 4
Yield gasoline, c.c.	17,000	16,000	16,310		9200	9600	11,300	
Gravity gasoline, deg. B.	85 2	85 5	85 8		80 5	80 3	82 3	
Gravity of refrigerator gasoline, deg. B.	91 1	91 8	90 5		90 3	92 0	90 6	
Volume of refrigerator gasoline, c.c.	1860	2200	2030		2335	2130	1810	
Amount of gas passed, cubic feet.	73,800							
Yield of gasoline per 1000 cu. ft., total pints		1	57			1 18		
Flow of gas—24,600 cu. ft. per hour.					Rate of flow of gas—21,600 cu. ft. per hour.			
Gallons of oil circulated per 1000 cu. ft. of gas—7.9.					Gallons of oil circulated per 1000 cu. ft. of gas—8.7.			

yield increased from 0.71 pint to 1.97 pints as the pressure was increased from atmospheric to 110 lb. per square inch. This is to be expected.

In using these small absorbers they were arranged in series of three for each test. The gas first passed through one absorber where most of the gasoline was extracted and then through the other two.

AMOUNT OF OIL USED PER THOUSAND CUBIC FEET OF NATURAL GAS TO OBTAIN THE LARGEST YIELD OF GASOLINE

A large number of tests were made with different absorbers to determine the proper amount of oil to be used per 1000 cu. ft. of natural gas in order to obtain the highest yield of gasoline. It was found that using the absorber shown in Fig. 2 the best results were obtained when about 7 gal. of oil were circulated per 1000 cu. ft. of gas. Using the tower absorber shown in Fig. 3 the amount of oil circulated could be considerably decreased and just as good results obtained by circulating 4 gal.

TABLE IV—EFFECT OF PRESSURE ON YIELD OF GASOLINE

Date	January 26, 1916	January 29, 1916	January 30, 1916	January 30, 1916	January 31, 1916
Time	2.45 to 3.58 p.m.	2.25 to 3.40 p.m.	9.35 to 10.45 a.m.	1.05 to 2.25 p.m.	8.15 to 9.37 a.m.
No. of absorber	3	3	3	3	3
Kind of oil used	Mineral Seal	Mineral Seal	Mineral Seal	Mineral Seal	Mineral Seal
Specific gravity at oil, degrees Beaume	34.2	35.0	35.0	34.2	34.2
Amount of oil used, cubic centimeters	1,750 1,500 1,500	1,750 1,500 1,500	1,750 1,500 1,500	1,750 1,500 1,500	1,750 1,500 1,500
Pressure on absorber, lb. per sq. in.	Atmospheric	20 lb. gage	40 lb. gage	85 lb. gage	110 lb. gage
Gas rate by meter, cu. ft. per hour	17,500 15,000 15,000	17,500 15,000 15,000	17,500 15,000 15,000	17,500 15,000 15,000	17,500 15,000 15,000
Ratio, c. c. of oil to 1000 cu. ft. of gas	100 100 100	100 100 100	100 100 100	102 102 102	100 100 100
Cu. ft. of gas consumed	1,770 1,505 1,510	1,845 1,515 1,520	1,825 1,555 1,535	1,850 1,550 1,545	1,875 1,575 1,550
Amount of liquid recovered, c. c.	35.1 34.5 34.4	35 35.2 34.7	35.7 35 34.8	35.4 35.2 35.2	36.7 35.5 35.5
Sp. gr. of liquid recovered, degrees Beaume	68 68 66	66 68 69	64 68 69	63 70 70	64 66 66
Temperature of liquid recovered, degrees Fahr.	1.2 0.6 0.3	2.3 1.2 0.5	2.6 1.0 0.9	2.8 1.02 0.8	2.8 1.0 0.8
Per cent saturation of liquid recovered	20 5 10	95 15 20	75 55 35	100 50 45	125 75 50
Increase in c. c. of liquid recovered	1.1 0.3 0.7	5.4 1.0 1.3	4.3 3.7 2.3	5.14 3.3 3	7.15 5.0 3.3
Increase, per cent, of liquid recovered					
Amount of sample, cubic centimeters (for distillation)	590 502 503	615 505 506	608 518 512	617 516 515	617 516 515
Temperature of condenser bath, degrees Fahr.	48 48 48	46 46 46	46 sample lost	52 52 52	48 48 48
Amount of distillate, c. c.	7.0 3.0 1.5	14.0 5.8 2.7	15.6 5.2 before	20.8 5.2 4.0	21.1 3.0 1.0
Temperature range of distillate, degrees Fahr.	165-260 190-260	160-260 138-260	130-260 Distillation	120-260 130-260	120-260 130-260
Amount of gasoline obtained, c. c.	21.0 9.0 4.5	42.0 17.4 8.1	46.8 15.6	62.4 15.6 12.0	63.3 3.0 1.2
Amount of gasoline obtained, pints per M cu. ft.	0.44 0.19 0.08	0.838 0.365 0.171	0.989 0.33	1.31 0.33 0.25	1.34 0.6 0.025
Sp. gr. of gasoline, degrees Beaume					
Total pints of gasoline per M cu. ft. of gas	0.71	1.427	1.489 Estimated loss 0.17 (See previous test)	1.89	1.97

of oil per 1000 cu. ft. of gas. Instead of decreasing the amount of oil, the practice of the authors was to keep the oil rate at about 7 gal. and increase the gas rate. The best results were obtained by using the tower absorber and passing about 28,000 cu. ft. of gas per minute and circulating about 7 to 8 gal. of oil.

DISTILLATION TEST OF GASOLINE

The gasoline obtained by absorption in mineral seal oil and steam distillation rather consistently had a specific gravity on the Beaumé scale of about 80 deg. One of many distillation tests that the authors made of it is shown in Table V. These tests were made on gaso-

TABLE V—DISTILLATION TEST OF GASOLINE OBTAINED BY ABSORPTION METHOD

Distillation Temperature, Degrees Fahrenheit	Amount of Distillate by Volume, per Cent	Specific Gravity of Distillate, Degrees Beaumé
80-110	10	91.8
110-124	20	89.0
124-136	30	86.7
136-146	40	83.4
146-158	50	80.4
158-172	60	77.4
172-188	70	73.3
188-208	80	70.2
208-244	90	65.0
244-290	93	63.1
Loss	7	

Experimental plant, December 29, 1915.
Specific gravity of mixture = 30° Beaumé.

line obtained from the large scale experimental plant shown in Fig. 2.

TABLE VI—EVAPORATION LOSS OF GASOLINE

Kind of Gasoline	From Absorption Process	Refinery
Specific gravity of gasoline at start, degrees Beaumé	81.1	60.4
Temperature of gasoline, degrees Fahrenheit	56	62
Temperature of room, degrees Fahrenheit	56	62
Volume of gasoline at start, cubic centimeters	1000	1000
Volume of gasoline after 24 hours, cubic centimeters	895	976
Volume of gasoline after 48 hours, cubic centimeters	840	935
Volume of gasoline after 72 hours, cubic centimeters	800	924
Specific gravity of gasoline after 24 hours, degrees Beaumé	79.6	
Specific gravity of gasoline after 48 hours, degrees Beaumé	76.5	
Specific gravity of gasoline after 72 hours, degrees Beaumé	76.0	58
Temperature of gasoline after 24 hours, degrees Fahrenheit	56	
Temperature of gasoline after 48 hours, degrees Fahrenheit	56	
Temperature of gasoline after 72 hours, degrees Fahrenheit	61	60
Evaporation loss of gasoline after 24 hours, per cent	10.5	2.4
Evaporation loss of gasoline after 48 hours, per cent	16.0	4.5
Evaporation loss of gasoline after 72 hours, per cent	20.0	7.6

EVAPORATION LOSS OF GASOLINE OBTAINED BY ABSORPTION PROCESS FROM NATURAL GAS AND A COMPARISON WITH DIFFERENT BLENDS AND WITH REFINERY GASOLINE

In Table VI there is shown the loss by evaporation, using different grades of gasoline. The liquids were ex-

posed in glass cylinders, 12 in. high, 4 in. in diameter, and of 1000 cubic centimeters capacity. The first column shows the evaporation loss when the gasoline obtained from natural gas by the absorption process was exposed to the air. The second column shows the evaporation loss, using refinery gasoline obtained from the Standard Oil Company.

CHANGE IN COMPOSITION AND QUANTITY OF THE NATURAL GAS BEFORE AND AFTER THE EXTRACTION OF GASOLINE

Tests which the authors made of the natural gas before and after treatment for the absorption of gasoline are given in Table VII. Natural gas from two lines was tested, low field gas and line L gas.

TABLE VII—TESTS OF FRESH GAS—COMBUSTION ANALYSIS

	Low Field Gas, per Cent	Line L Gas, per Cent
CO ₂	Trace	Trace
CH ₄	76.3	83.9
C ₂ H ₆	19.4	11.7
N ₂	5.3	4.4
Total	100.0	100.0
Specific gravity	0.68	0.63
Absorption in Russian white oil*	17.0	15.0
Gross heating value per cubic foot at 0 deg. C. and 760 mm. pressure	1155.0 B.t.u.	1111.0 B.t.u.

*This Russian white oil is used in the same way that claroline is used, and described on page 32, Bull. 83, Bureau of Mines.

The tests of Table VII were made of gas that had not been treated by the absorption process. Table VIII shows tests of the same gas after it had been passed through absorbers containing mineral seal oil, and after gasoline had been extracted from it.

TABLE VIII—TESTS OF TREATED GAS—COMBUSTION ANALYSIS

	Low Field Gas, per Cent	Line L Gas, per Cent
CO ₂	Trace	Trace
CH ₄	79.7	88.3
C ₂ H ₆	14.1	7.9
N ₂	6.2	3.8
Total	100.0	100.0
Specific gravity	0.65	0.61
Absorption in Russian white oil	16.7	14.0
Gross heating value per cubic foot at 0 deg. C. and 760 mm. pressure	1111.0 B.t.u.	1087.0 B.t.u.

COMMENTS ON ANALYSES

Differences between the natural gas before and after gasoline had been extracted are interesting. In the case of the low field gas, the heating value was lowered 44 B.t.u. or 3.8 per cent, due to the extraction of the

gasoline. The specific gravity dropped from 0.68 to 0.65 and the proportions of paraffin hydrocarbons, calculated as methane and ethane, were altered. In the case of Line L gas, the heating value was lowered 24 B.t.u. or 2.2 per cent and the specific gravity dropped from 0.63 to 0.61.

The quantity of natural gas that disappears due to the extraction of the gasoline is small. It can be calculated as follows: The assumption can be made that the gasoline extracted is all pentane. This assumption is close enough for the purpose. One gallon of pentane produces about 32 cu. ft. of vapor or about 16 cu. ft. of the natural gas are removed for each 4 pints of gasoline extracted. Four pints of gasoline probably represent the maximum of vapor extracted for each two pints of gasoline produced.

VAPOR-TENSION TESTS OF GASOLINE OBTAINED BY OIL ABSORPTION AND STEAM DISTILLATION

Many vapor-tension tests were made of the gasoline. Some of these tests are shown in Table IX. It will be seen that the material does not develop excessive pressures with rise of temperature and that it comes well within the specification for gasoline that can be shipped in tank cars.

TABLE IX—VAPOR PRESSURE TESTS OF GASOLINE PRODUCED BY OIL ABSORPTION AND STEAM DISTILLATION PROCESS

Date	12-15-15	12-16-15	12-22-15	12-23-15
Specific gravity of gasoline, deg. B.....	79	78	77.5	81.5
Vapor pressure, at 70 deg. F., lb. per sq. in....	1.25	1.0	0.5	1.25
Vapor pressure at 90 deg. F., lb. per sq. in....	1.50	1.5	1.0	2.0
Vapor pressure at 100 deg. F., lb. per sq. in....	2.75	2.5	2.5	4.75

The rules of the Interstate Commerce Commission¹¹ regarding the shipment of natural gas gasoline follow.

REGULATIONS FOR THE TRANSPORTATION ON RAILROADS OF NATURAL GAS GASOLINE

"Liquefied petroleum gas is a condensate from the 'casing head gas' of petroleum oil wells, whose vapor-tension at 100 deg. Fahr. (38 deg. C.) to 90 deg. Fahr. (32 deg. C.), Nov. 1 to March 1, exceeds 10 lb. per square inch. Liquefied petroleum gas must be shipped in metal drums or barrels which comply with 'shipping container specification 5' or in tank cars especially constructed and approved for this service by the Master Car Builders' Association. When the vapor tension at 100 deg. Fahr (38 deg. C.) exceeds 25 lb. per square inch, cylinders as prescribed for compressed gas must be used."

UNCONDENSED VAPORS FROM THE STILL

In the process of distillation of the gasoline from the mineral seal oil by means of steam, an appreciable quantity of uncondensed vapors escaped into the air, hence some of them were liquefied by passing the vapors through a 1-in. pipe about 8-ft. long, inside another pipe 2 in. in diameter and 8 ft. long. Compressed natural gas which had been used to run one of the oil pumps (in place of steam) was expanded through the larger pipe to cool and condense as much of the vapors as possible. A temperature of 0 deg. to 4 deg. Fahr. was obtained in this manner. Table X shows the vapor pressure and other data regarding these condensed vapors, using the plant shown in Fig. 2.

The yield of gasoline obtained from the steam still during this test was 0.94 pints of 80 deg. Beaumé gaso-

TABLE X—DATA REGARDING UNCONDENSED VAPORS FROM STILL VAPORS FROM CONDENSER, PLANT 2, DECEMBER 28, 1915

130,000 cu. ft. of natural gas used in the test and 450 cu. ft. of vapor passed through refrigerator.					
Yield: 3½ gallons per 130,000 cu. ft. of natural gas used at plant.					
Vapor tension test.....		5 lbs. at 70 deg. F. 8½ lbs. at 90 deg. F. 11 lbs. at 100 deg. F.			
Specific gravity of refrigerator gasoline.....		94.9 deg. Beaumé			
EVAPORATION TEST					
Time, p.m.....	1:15	1:20	1:35	2:00	2:15
Volume (cc.).....	100	75	65	55	50
Temperature, deg. F.....		60	70	84	90
Per cent loss.....		25	35	45	50

line per 1000 cu. ft. of gas. The yield of gasoline from the refrigerator was 3¼ gal. per 130,000 cu. ft. of natural gas, or 0.2 pints per 1000 cu. ft.; hence 0.2 plus 0.94 pints = 1.14 pints total yield.

EFFECT OF PRESSURE AND TEMPERATURE ON THE ABSORPTION OF GASOLINE FROM NATURAL GAS

The authors found that the yield of gasoline was considerably affected by the pressure under which the absorption was effected. This is to be expected. In one test an increase in the pressure of the gas from atmospheric to 110 lb. per square inch increased the yield from 0.7 pint to about 1.97 pints per 1000 cu. ft. of gas.

An increase in the temperature of the oil in the absorber from about 75 deg. Fahr. to 85 deg. Fahr. lowered the yield about 0.3 pints per 1000 cu. ft. of gas.

COST DATA

As a result of the experiments conducted to date, a much larger plant is contemplated, capable of handling about 50,000,000 cu. ft. of natural gas per day. Exact figures regarding the cost of installing such a plant cannot be given at the present time. It is believed, however, that a conservative estimate is \$1.00 to \$1.50 per thousand cu. ft. of gas handled per day for a "plant" capable of handling 60,000,000 to 90,000,000 cu. ft. and up to \$2.00 per 1000 cu. ft. of gas for a plant of 30,000,000 cu. ft. or less. The returns are large. At \$1.00 per 1000 cu. ft., a plant to handle 60,000,000 cu. ft. would cost \$60,000. If only one pint of gasoline was extracted from each 1000 cu. ft. of gas per day, there would be extracted from 60,000,000 cu. ft. 7500 gal. of gasoline. At \$0.20 per gallon for gasoline, this is \$1,500 per day.

Combination Process of Absorption of Gasoline from Natural Gas by Means of Naphtha and Mineral Seal Oil

This process, heretofore described, of extracting gasoline from natural gas by absorption, consisted in first passing the natural gas through mineral seal oil and then separating the absorbed gasoline from the oil by steam distillation. This process resulted in obtaining from one gas line about 1.2 pints of gasoline per 1000 cu. ft. of gas, and from another line about 1.8 to 1.9 pints of gasoline. This has reference to tests made with the small absorber shown in Fig. 2.

In using the mineral seal oil as the absorbent, it was found that the increase in volume of the mineral seal oil after passing natural gas through it, did not correspond with the quantity of gasoline subsequently obtained from the oil by distillation. This was due to the fact that a considerable quantity of the lighter hydrocarbons was absorbed from the natural gas, increasing the volume of the mineral seal oil, but escaping as a gas when the oil was subjected to distillation to obtain the absorbed gasoline.

The loss of material appeared to be considerable, so a solution was sought that would result in obtaining this material wasted by the oil absorption and distillation process. Therefore several tests were made, using the

¹¹From "Regulations of the Interstate Commerce Commission for the Transportation of Explosives and Other Dangerous Articles by Freight and Express, and Specifications for Shipping Containers," published by the Bureau for the Safe Transportation of Explosives and Other Dangerous Articles, in January, 1912; effective March 31, 1912.

TABLE XI—EXTRACTION OF GASOLINE FROM NATURAL GAS BY PASSING THE LATTER THROUGH NAPHTHA LINE L GAS

Test No.	1			2			3			4			5			6		
Oil or naphtha used.	Naphtha	Naphtha	Mineral Seal	Naphtha	Naphtha	Mineral Seal	Naphtha	Naphtha	Mineral Seal	Naphtha	Naphtha	Mineral Seal	Naphtha	Naphtha	Mineral Seal	Naphtha	Naphtha	Mineral Seal
Sp. gr. of oil or naphtha, deg. B.	53.5	53.5	32.9	55.5	55.5	34.2	55.5	55.5	33.9	55.5	55.5	34.2	55.5	55.5	34.2	55.0	65.0	34.2
Pressure on gas, lb. per sq. in.	235	235	235	230	230	230	235	235	235	235	235	235	235	235	235	235	235	235
Gas rate, cu. ft. per hour.	50	50	50	55	55	35.3	180	180	180	54	54	54	180	180	180	56	56	56
Amount of gas used, cu. ft.	200	200	200	105	105	105	200	200	200	217	217	217	100	100	100	202	202	202
Oil used, c. c.	1750	1500	1500	1750	1500	1500	1750	1500	1500	1750	1500	1500	1750	1500	1500	1750	1500	1500
Oil recovered, c. c.	1950	1640	1565	1925	1560	1510	1850	1555	1600	2040	1600	1560	1810	1525	1560	2020	1505	1530
Sp. gr. of liquid recovered, deg. B.	61.6	60.0	37.7	59.6	58.0	36.3	58.2	54.8	36.2	62.0	58.6	36.1	57.3	66.8	35.9	60.9	58.9	36.1
Temperature of liquid in absorber, deg. F.	27	29	26	19	19	19	54	54	60	28	28	26	60	60	66	18	18	18
Increase in liquid in absorber, c. c.	200	140	65	175	60	10	100	55	100	290	100	60	60	25	60	270	95	30
Percentage increase in liquid in absorber																		
Sample of mineral seal oil for distillation.			500			503			533			520			520			500
Amount of gasoline distilled from mineral seal oil, c. c.			7			2			25			7			16			5.6
Yield of gasoline, pints per 1000 cu. ft. of gas.	2.114	1.480	0.687	3.53	1.21	0.12	1.06	0.58	1.06	2.92	0.97	0.21	1.27	0.53	1.27	2.90	0.99	0.17
Total yield, pints per 1000 cu. ft. of gas.		4.28			4.86			2.70			4.10			3.07			4.06	

small absorbers of the type shown in Fig. 2 with naphtha, specific gravity 55 deg. Beaumé in the first two absorbers and mineral seal oil in the third absorber. The object was to absorb as much of the gasoline as possible, including the lighter hydrocarbons, in the first two absorbers and the rest of the gasoline in the mineral seal oil. Table No. XI shows the results of these tests.

COMMENTS ON TESTS

It will be observed that the gasoline extracted from the natural gas by passing the latter through naphtha amounted to 4.86 pints per 1000 cu. ft. of gas in the case of one test. The lowest yield was 2.70 pints. The increase in yield over the oil absorption and distillation method varied between 300 and 500 per cent.

In test 1 the specific gravity of the naphtha was raised from 53.5 deg. Beaumé to 61.6 deg. Beaumé in the first absorber and to 60 deg. Beaumé in the second absorber. The increase in volume of the naphtha in first absorbers was 200 c. c. or 11.5 per cent, and in the second absorber 140 c. c. or about 9.3 per cent.

The greatest increase in volume and specific gravity of the naphtha was obtained in No. 1 absorber, test 4. The specific gravity of the naphtha was raised from 55.5 deg. Beaumé to 62 deg. Beaumé and the increase in volume was 290 c. c. or about 16.6 per cent.

The vapor pressure of the resulting naphtha in No. 1 absorber, test 4, was 5 lb. per square inch at 100 deg. Fahr., and the evaporation or weathering loss was 5 per cent in 24 hours. During this weathering test the temperature of the gasoline increased from 54 deg. Fahr. at the start to 64 deg. Fahr. at the finish. The temperature of the room changed from 56 deg. Fahr. to 64 deg. Fahr.

The temperature of the naphtha had much influence on the results of the tests. The highest yield was that shown in test 2 where the temperature of the naphtha was 19 deg. Fahr. This test was conducted in the open air on a cold winter day. However, even at a temperature of 60 deg. Fahr. a yield as high as 3.07 pints of gasoline per 1000 cu. ft. of gas was obtained. Test No. 6 was instructive in that the vapor pressure of the resulting naphtha in No. 1 and No. 2 absorbers was 14 lb. per square inch at 100 deg. Fahr. In other words, its vapor pressure exceeded that prescribed for gasoline to be shipped in tank cars.

In summing up the use of naphtha as an absorbent for extracting gasoline from natural gas, it can be stated that a greater yield can be obtained than by using the oil absorption and distillation process, as much as 300 per cent greater at ordinary temperatures and 400 to 500 per cent greater if temperatures as low as 18 deg. to 19 deg. Fahr. are employed. A further advantage lies in the fact that the resulting naphtha with its absorbed gasoline does not have to be subjected to dis-

tillation to obtain gasoline but can be sold as prepared.

An objection to it lies in the fact that a large amount of naphtha would have to be handled in large-scale operations. Mineral seal oil can be used over and over again with but slight loss while the naphtha would have to be constantly received.

The greatest increase in volume of the naphtha was 16.6 per cent in test 4. This amounts to about 6 to 7 times as much naphtha as gasoline, i. e., for each tank of gasoline extracted from the natural gas there would be needed 6 or 7 tanks of naphtha. One cannot absorb too much gasoline in the naphtha else the vapor pressure of the resulting mixture exceeds the limit (10 lb. per square inch at 100 deg. Fahr.) set for the transportation of gasoline in tank cars.

If an absorption gasoline plant could be located at or close to a refinery where a large supply of naphtha was available, the difficulty and trouble of transporting large quantities of naphtha into the absorption plant would be largely overcome, but in most, and perhaps all, cases this is not feasible. A real obstacle at the present time is the difficulty of getting naphtha.

One can look at the problem in the following way:

By the oil absorption process there is obtained one-third as much gasoline as by the naphtha process. One tank car (10,000 gal.) of the absorption process gasoline sells for about 20 cents per gal., or \$2,000. (This figure, however, will vary.) Three tank cars will sell for \$6,000, or an increase of \$4,000. But in order to secure this increase of \$4,000, about seven tank cars of naphtha would have to be brought into the absorption plant, i. e., seven times as much naphtha would have to be handled as of gasoline extracted.

Adaptability of the Absorption Process to Casing-Head Natural Gas

The authors have not made experiments to date regarding the applicability of the absorption process to casing-head natural gas, i. e., natural gas containing a comparatively large proportion of gasoline vapor and at present treated by compression and condensation methods.

The "dry" natural gases used in the experiments described in this report contained from 1 to 2 pints of gasoline per 1000 cu. ft. of gas, and at least 4 gal. of absorbing oil were calculated for 1000 cu. ft. of gas to obtain the highest yield of gasoline. On the same basis, about 32 gal. of oil would have to be circulated for each 1000 cu. ft. of casing-head natural gas that carried 1 gal. of gasoline per 1000 cu. ft. of gas, or about 64 gal. of oil for casing-head natural gas containing 2 gal. of gasoline per 1000 cu. ft. of gas. If 30,000 cu. ft. of gas per hour were treated, then $30 \times 64 = 1920$ gal. of oil would have to be circulated per hour. There are many casing-head compression plants treating 30,000 to

50,000 cu. ft. per hour and obtaining 2 gal. of gasoline per 1000 cu. ft. of gas.

Another possibility is the working of the two processes together on casing-head gas. The gas might be compressed and condensed in the ordinary manner first and the exit gases passed through a small absorbing plant to extract gasoline not completely extracted by the compression method. Waste gases from compression plants contain gasoline that has not been completely extracted. It does not do any good to pass them back through the plant again because they would be subjected to the same process as before, but it might be feasible to pass them through an absorption plant. A point in favor of the absorption process as compared to the compression and condensation method lies in the fact that the gasoline obtained by the former process is not so "wild" as that usually obtained by the latter method.

At present the application of the process to casing-head gases is largely conjecture on the part of the authors, but experiments will be conducted in the future along this line. However, one is safe in saying that there is a great deal of casing-head natural gas at present going to waste that, while considered too lean to work by the compression method, could be treated by the absorption method.

Summary

The absorption method of extracting gasoline from natural gas consists in bringing natural gas in contact with an oil heavier than gasoline, *i.e.*, a petroleum distillate of about 34 deg. Beaumé, letting the absorbent absorb the gasoline from the natural gas, and then separating the gasoline from the oil by distillation. The oil is simply used as a carrier of the gasoline from the absorption tank to the still. It is used over and over again.

This method is different than the extraction of gasoline from casing-head natural gases by compression and condensation methods. By the latter method natural gases that are comparatively rich in gasoline vapor are treated, *i.e.*, those carrying upwards of $\frac{3}{4}$ gal. of gasoline per 1000 cu. ft. of natural gas. So-called "dry" natural gas cannot be treated by this method. By "dry" natural gases are meant those used in cities, towns and factories for heating, lighting and other purposes. The quantity consumed of this kind of natural gas amounted in 1914 to 591,000,000,000 cu. ft. Most of this natural gas carries gasoline to the extent of 1 to 2 pints per 1000 cu. ft. of gas. Probably 75,000,000 gal. of gasoline per year can be obtained by treating much of this natural gas at the present time.

In the case of two natural gases that the authors of this paper experimented with, the heating value was only lowered 3.8 per cent in one case and 2.2 per cent in another case by the extraction of the gasoline.

Besides the obtaining of valuable fuel, gasoline, a further advantage of the process lies in the resultant protection of pipe lines against the deteriorating effect of gasoline on coupling rubbers. The replacing of these rubbers and the repairing of broken connections and loss of natural gas thereof has been a large item of expense in gas transportation companies' operating costs.

The absorption process of extracting gasoline from natural gas assumed industrial importance as the demand for gasoline increased. The scheme is practically identical with the process of extracting benzole and toluol (light oil) from coke-oven gases, a process used for years in Germany and to a very large extent during the years 1915 and 1916 in the United States. A difference lies in the fact that coke-oven gases are treated at about atmospheric pressure while natural gas is treated

at pressure as high as 200 to 300 lb. per square inch. This is an economic necessity because natural gas is transported at high pressures, and it is not desirable to disturb the system.

To the best of the authors' knowledge the first large-scale installation for extracting gasoline from natural gas by the absorption process was placed at Hastings, W. Va., by the Hope Natural Gas Company of Pittsburgh, Pa. Operations commenced in 1913. The plant was built following experiments by George M. Saybolt.

Natural gas can be tested as regards the practicability of extracting gasoline from it by the absorption process by two methods. One is a laboratory method whereby the gasoline is frozen out of the natural gas and its pressure and volume determined. The other method is a field method.

A small absorber and a gas meter can be taken to the well or pipe line to be tested for natural gas, the gas passed through the absorbent and the extracted gasoline distilled from the oil. In other words, a duplicate on a small scale of the commercial method.

All natural gases, except those that contain methane only as the combustible gas, contain gasoline vapor. However, in some cases the amount contained may be very small. This is sometimes due to the fact that gas wells are under very high pressures, and this high pressure keeps the gasoline back in the well. But even those high-pressure wells represent potential sources of gasoline supply in that natural gas will carry commercial quantities of gasoline vapor as the pressure declines.

Natural gas from two different fields that the authors tested contained gasoline to the extent of 1 pint per 1000 cu. ft. in one case and 1.5 pints in another case. About 50,000,000 cu. ft. of natural gas per day was available for treatment.

Oils which the authors experimented with to act as absorbents for the gasoline were about 35 deg. Beaumé specific gravity and started to boil at about 400 deg. to 462 deg. Fahr. They were petroleum distillates. It is necessary that their boiling point be much higher than the boiling point of the gasoline to make the extraction of the latter by distillation easy.

Tests were made on a plant of fairly large proportions, capable of handling 15,000 to 30,000 cu. ft. of gas per hour. The plant consisted of an absorber where the natural gas and absorbent oil were brought in contact with each other, a heat exchanger where the oil with its absorbed gasoline was heated before going to the still, a steam still where the gasoline was extracted from the oil, a cooler where the hot oil from the still was cooled before receiving another charge of gasoline, pumps, weathering tank, etc.

Several different types of absorbers were tried. The one giving the best results consisted of a stone tower down which the oil flowed and up which the gas passed.

An increase in the temperature of the oil in the absorber from about 75 deg. Fahr to about 85 deg. Fahr. lowered the gasoline yield about 0.3 pint per 1000 cu. ft. of gas. An increase in the pressure of the gas from atmospheric pressure to 110 lb. per square inch increased the yield from 0.7 pint to about 1.9 pints of gasoline per 1000 cu. ft. of gas.

The specific gravity of the gasoline obtained varied between 77 deg. Beaumé and 85 deg. Beaumé. The boiling points ranged from 80 deg. Fahr to 300 deg. Fahr. The evaporation loss was about 11 per cent in 24 hours as compared to straight refinery gasoline 60.4 deg. Beaumé, having an evaporation loss of about 2.4 per cent in 24 hours. The vapor pressure of the gasoline ranged from 1 lb. at 70 deg. Fahr. to about 5 lb. at 100 deg. Fahr. This is important because it shows that the gasoline can be shipped in tank cars.

Some tests were made in which the natural gas was simply passed into a naphtha of about 55 deg. Beaumé. When the naphtha had absorbed all the gasoline that was desired it was removed and fresh naphtha substituted. By this scheme there were obtained yields of gasoline varying between 300 and 500 per cent greater than that by the oil absorption and distillation process. In some cases the naphtha, besides being increased in volume due to the absorbed gasoline, was raised in specific gravity to 60 deg. or 62 deg. Beaumé. An objection to the process lies in the fact that a large amount of naphtha has to be handled—at least seven tanks of naphtha for each tank of gasoline obtained.

There are possibilities in the application of the absorption method of treating natural gas to the casing-head natural gas, much of which is treated at the present time by compression and condensation methods.

The authors of this report are indebted to C. F. Ward and A. M. Ballard, engineers of the Ohio Fuel Supply Company, who rendered valuable aid during the entire experiments, and to Dr. G. A. Hulett, consulting chemist of the Bureau of Mines, for assistance in conducting the naphtha absorption experiments.

Cost-Accounting in the Construction and Operation of a Copper Smelter

BY ERNEST EDGAR THUM, E.M.*

Operating Accounts

After the completion of a unit of the plant, operations will commence immediately. In fact, the urgency to blow in may be so pressing that operations will be started long before the finishing touches have been given to the department. It is evident, therefore, that a clear distinction should be made between operating and construction accounts. This may easily be done by prefixing "O" (operating) before the main account number, and using letters for sub-numbers; thus retaining a close correlation between construction and operating accounts in conjunction with a sharp differentiation.

A list of operating accounts for our smelter will now be given.

STORAGE-BINS OPERATING EXPENSES; ACCOUNTS O 10 TO O 19

Ore-Bedding Plant	O 10
Thawing Shed	O 11
Sampling-Mill Bins	O 12
Blast-Furnace Bins	O 13
Roaster Bins	O 14
Reverberatory Bins	O 15
Converter Bins	O 16
Flue-Dust Bins	O 17
Boiler-House Bins	O 18

SAMPLE-MILL OPERATING EXPENSES; ACCOUNTS O 20 TO O 29

General	O 20
Crushing, Elevating, Screening and Cutting	O 21
Conveying	O 26
Power Transmission	O 27
Bucking, making up samples	O 28

BLAST-FURNACE PLANT OPERATING ACCOUNTS; ACCOUNTS O 30 TO O 39

General	O 30
Smelting	O 31
Water Supply	O 34
Elevating	O 35
Sluicing	O 36

ROASTING-PLANT OPERATING ACCOUNTS; ACCOUNTS O 40 TO O 49

General	O 40
Smelting	O 41
Jacket Water	O 44
Elevating	O 45
Conveying	O 46
Power transmission	O 47

REVERBERATORY-PLANT OPERATING ACCOUNTS; ACCOUNTS O 50 TO O 59

General	O 50
Smelting	O 51
Waste-Heat Boilers	O 54
Fuel Plant	O 55
Sluicing	O 56
Lining Ladles	O 59

CONVERTER-PANT OPERATING ACCOUNTS; ACCOUNTS O 60 TO O 69

General	O 60
Smelting	O 61
Crane Work	O 64
Casting Slag	O 65
Refining Copper	O 66
Casting Copper	O 67
Loading Copper	O 68
Lining Ladles	O 69

MAIN FLUE AND STACK OPERATING ACCOUNTS; ACCOUNTS O 70 TO O 79

General	O 70
Refining Fume	O 71

BOILER-HOUSE OPERATING EXPENSES; ACCOUNTS O 80 TO O 89

General	O 80
Fuel	O 81
Washing	O 82
Stoking	O 85
Handling Ashes	O 86
Condensing	O 87
Feed Water	O 88

POWER-HOUSE OPERATING EXPENSES; ACCOUNTS O 90 TO O 99

General	O 90
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TRAMMING AND WEIGHING OPERATING EXPENSES; ACCOUNTS O 110 TO O 119

Interconnecting	O 110
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Slag Trucks	O 112
Blast-Furnace Charging Tracks	O 113
Roaster Charging Tracks	O 114
Reverberatory Charging Tracks	O 115
Converter Charging Tracks	O 116
Flue-Dust Tracks	O 117
Copper Tracks	O 118

SHOPS' OPERATING EXPENSES; ACCOUNTS O 120 TO O 129

Machine Shop	O 120
Smelter Mechanics Shop	O 121
Boiler Shop	O 122
Blacksmith Shop	O 123
Carpenter Shop	O 124
Pipe Shop	O 125
Electricians Shop	O 126
Bricklayers and Masons Shop	O 127
Locomotive and Car-Repair Shop	O 128
Crane-Repair Shop	O 129

MISCELLANEOUS OPERATING EXPENSES; ACCOUNTS O 130 TO O 150

General Office	O 130
Laboratory	O 131
Change House	O 132
Warehouse	O 133
Outside Toilets	O 137
Watchmen	O 138
General Yard	O 140
Yard Lighting	O 141
Fire Department Expense	O 144
Water Development	O 145
Telephone System	O 146
Weather Bureau	O 147

The operating accounts are susceptible of uniform subdivision in an analogous manner to the construction accounts. The general accounts of the O 20 class may be subdivided as follows:

- A Lighting and Heating; including
 - Wages of caretakers.
 - Globes, carbons, cocks and supplies of short life.
 - Electric current.
 - Steam.
- B Superintendents and Clerks; Salaries and Supplies.
- C Allowance for Depreciation.
- D Allowance for Repairs and Renewals.
- E Unclassified; including
 - Labor and supplies not chargeable elsewhere.
 - Per cent of miscellaneous operating expenses.
 - Per cent of unlisted overhead expense.

To this list should be added, in the case of Account O 90, "power house," another subdivision covering the wages of tenders, and oilers, together with such supplies as oil, grease, waste, packing, belt-dressing, and charts. The account for power-house operating has not been subdivided into various classes of equipment owing to the fact that it is usually impossible to properly distribute such items to the different engines unless the installation is an unusually large one, or different classes are housed in different buildings. This account, together with others as noted, is an "expense" and will be distributed in this particular case into the operating accounts proportionately to their power consumption. A method of handling such expenses in such a manner that the rates charged for power may be constant for a fiscal year, has already been discussed at some length, and need not be further dwelt upon in this place.

The very important accounts classed as "smelting"

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(O 41 class) should be minutely subdivided in the following manner:

- A Proportion of storage-bin expense chargeable to department material.
- B Proportion of trampling and weighing expenses chargeable to feeding furnaces. Includes cost of trampling flue dust from any source to this department.
- C Furnacemen.
- D Flues.
- E Fuel.
- F Blast (proportion of power-house expense).
- G Firemen.
- H Sampling, plus proportion of sampling-mill operating expense.
- I Assaying (proportion of laboratory operating expense).

The above will indicate how the various "operating expenses" will be absorbed by the producing departments, and the net result of the accountants' labors will be a statement showing all legitimate expenses of every kind incorporated into the total cost of metal production. The receipts for the sale of this metal must evidently be greater than the total cost of production in order that the company remain solvent.

Importance of Operating Accounts

The remarks made hitherto regarding the desirability of maintaining a proper cost system in addition to the bookkeepers' accounts, the method of collecting and recording information about the labor, material and expense incurred, the necessity of accurate estimation of stocks on hand and material in process, apply with even greater emphasis to the keeping of operating costs, accounts and expenses. The costs will show very graphically the condition of affairs in each department. The departmental heads will receive periodic comparative statements of their condition with certain pointed remarks appended, and it will only be a short time before each man in the works will feel the influence of these figures spurring him toward greater efficiency. Further, the costs will afford the manager ample data for a careful study of the plant's operation leading toward the effecting of economies and the installation of improvements. We may with propriety reiterate our argument that scientific exactitude in the minutiae of costs is neither practicable nor desirable as a matter of daily routine, but the system should have such information latent, to be yielded upon demand. The accounting system should be rigidly exact; and in the end should show how much it cost to operate the industrial system. Many accounts will measure up to this mark, but few will reveal the cost of repairs and operation of "electric locomotive No. 5." Yet without such information the manager has little to guide him in the choice of the most economical traction for a new department.

Repair and Renewal Accounts

With the beginning of the wear and tear of operation will come the necessity of making expenditures for repairs and renewals. Every construction account will have its corresponding repair account bearing the same number and merely distinguished by the prefix "R".

52

Thus, if Account c — No. 2 covers the steelwork in the

4

flue connections for No. 2 Reverberatory, and it is desired to replace a broken tie-rod, the proper shop order will be made out by the reverberatory foreman, the work

52

done, and the entire cost charged to Account R — No. 2;

4

In case a bad accident should demolish this connection and thus cause repairs of considerable amount, costing above a fixed figure, say \$100.00, the superintendent will issue a repair order to the foremen who will be expected to do the work, giving directions as to the work

to be done, and instructing them to charge their expense

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to 1R — No. 2. Subsequent orders for large repair or

4

renewal jobs on the same equipment will be numbered serially 2R, 3R and so on. The significance of this nomenclature is evident: the first (1) repair order (R) for the steelwork (—) on reverberatory furnace (52)

4

number two (No. 2). All such repair expense will upon completion and closing of the order, be charged into

52

50

R —, and absorbed by the operating account O —.

4

D

It is evident that the account books made up for the construction foremen can be immediately put into use by the operating foremen. A construction account is transformed into a repair account of exactly the same significance and scope by simply prefixing "R" instead of "C". The operating accounts will be printed in a uniform manner with the construction or repair accounts, and added to the book, together with terse instructions as to the meaning and scope of each account and subdivision. Much repetition can be avoided by the formulation of general rules distinguishing between operating and repair charges, and by explaining that all accounts of the same class, "general," "furnace" or "shops" are to be uniform in designation and significance.

Improvements and Reconstruction

After our smelter has been in operation for some time there will arise the desirability of replacing units of equipment which have become worn out through age, or obsolete in consequence of improvements in the technology. Economy and policy will demand the installation of new departments to utilize by-products or eliminate nuisances. The proper handling of such accounts will now be considered.

We need not discuss at further length the accounting for extensions. A new department added to an old plant is as truly "new construction" as the construction of the original plant. A new series of accounts will be opened covering each new department, the costs during construction being obtained as before, and the total expense incurred will be borne by an appropriation from the general funds or by sale of stocks and bonds. The cost new will be added to the assets, as a part of the value of the plant. Suitable operating accounts will be opened and repairs, renewals and depreciation cared for in the usual manner.

A different procedure is necessary in the case of reconstruction. Suppose it becomes desirable to remove as obsolescent a steam-power plant before its value has been written off by depreciation, and substitute therefor a gas-producer and gas-engine plant. We will assume that the boiler house, constructed under Accounts C 80 to C 89 will be retained for furnishing steam for heating purposes and for blowing under the producers. The power-house equipment, however, will be nearly all replaced as rapidly as possible by the more modern machinery, utilizing with only minor changes the old building and certain pieces of the old equipment.

We will need to consider briefly the method of handling the following varieties of accounts:

- Extensions to old building.
- Minor alterations and adaptations in the old building.
- Present value of the old building.
- Dismantling and removing machinery and appurtenances.
- Present value of old machinery.
- Cost and erection of new machinery.
- Temporary changes necessary to keep operating.

The building was originally constructed under Account C 90, which was further segregated into some

score of sub-numbers. Since the commencement of operations each part of the building has had ample repair work done upon it to keep it in first class condition, and its actual worth as a building is far in excess of its present book value, which, we will assume, has been reduced to some 60 per cent of the original cost by allowances for depreciation.

The account covering "gas engine building" may be C 150, and will be subdivided exactly as the old account C 90. Each of these sub-accounts will bear the cost of any additions to the existing building or its appurtenances, the funds necessary being obtainable from capital account, and will form a legitimate basis for a corresponding increase in capitalization, the cost of such additions being added to "assets" as "value of plant." Minor alterations to the old building should be charged to the appropriate repair account; for instance, if the tool room has to be moved to make room for new machinery, such

90

expense should be borne by Account R —, inasmuch as

24

no value is actually added to the building by such an operation—a mere adaptation to the new conditions. On completion of the reconstruction, the book value of C 90 will be transferred into C 150, item to item, when the total of Account C 150 will represent the present value of the building in its enlarged and remodeled state. Obviously, future repairs to any part of the building, new or old, will be charged to R 150; Account 90 has ceased to exist.

A different state of affairs is encountered with Account C 93, covering "blast furnace blowers." We will assume that a battery of impeller blowers belted to a line-shaft driven by a steam-engine will be replaced by centrifugal blowers, direct-connected to motors. Evidently, little if any of the old installation can be utilized in the new, consequently a dismantling account with appropriate sub-numbers will be opened, called D 93, and the book value of C 93 will be transferred thereto, item to item, each of which will now be considered.

1. Excavation and Backfilling.
2. Foundation.
3. Floors and Paving.

The above will represent practically a dead loss. It will be unfair to charge No. 1 to the new account, as this will be charged with the necessary expense of blasting out the old foundations. The old foundations will actually be a hindrance to the new work, and will have no value to the new sub-number 2 except perhaps to furnish a little rubble. Any special floors and paving for an impeller installation can hardly be utilized as such.

4. Machinery and Erection. None of this will be utilized in the new installation. Cost of removal and

93

storing will be borne by Account D —.

4

6. Wiring and Lighting.
7. Steam Piping.
8. Water Piping.

All this will have to be torn out, which expense together with the present value will be borne by appropriate sub-numbers under the dismantling account D 93. This will represent almost a total loss, as little useful material will be reclaimed.

9. Air Piping. This sub-number will cover only the construction of the connections between each blower and the main transmission line, and must be removed. Considerable sheet-steel of value will be recovered, however.

It will be noted that this account represents almost the precise antithesis of the building account—none of it will be useful as such in the reconstruction. The special dismantling account must, therefore, bear the cost

of removal, and it will be credited with the receipts of sales of the reclaimed machinery and miscellaneous material when this is effected. The balance, and it is certain to be a large one on the debit side, must be charged into profit and loss, and eventually absorbed by the operating and producing departments.

Account C 93 has, therefore, ceased to appear in the general statement as an asset. Its place will be taken by C 153 which will represent the complete cost and installation of the new units, exactly as though they were installed in a new building on a new site. Any excess in the first cost of this new installation above the first cost of the old will be a legitimate item upon which to base an increase in capital stock. The balance of the funds for the new construction will be derived from the total depreciation allowed to Account C 93 plus the receipts from the transfer of the old blowers and machinery to the dismantling account D 93—now a "supply" account in that it holds sundry second-hand material pending sale.

These two cases discussed at some length represent the two extremes—every shade of gradation may occur in practice. They can be properly handled by considering the different subdivisions in one manner or the other—either of use, or of no use—and treating each item accordingly. Some items may be quite complicated, such as a job of re-wiring, improving and changing the arcs in a lighting circuit. The various kinds of work are so intermixed that segregation would be impracticable. In such an event, the value of the new equipment minus the first cost of the old would represent added value and is chargeable to assets. In this, as in all foregoing remarks, it is assumed that the ordinary method of corporate accounting is in use; such that the liabilities item "capital stock" retains a constant value. This requires that the sum of the two items "present value of plant" and "total allowances for depreciation" must constantly equal the first cost of installation, which cost was carried originally by an appropriation from the general funds.

In case the reconstruction of a department is undertaken during operation, another class of charges will occur, viz., temporary work which is required in order to keep the rest of the plant in operation. In our hypothetical case, suppose it was necessary to construct a by-pass in the air main around the site of the new installation, together with a temporary connection to the converter blowers with the proper pressure-reducing appliances. This work is made necessary by the new construction, but only because it is desired to keep the plant in operation during this period. Adding this expense to that of the new construction would increase its total cost above normal by these items representing no permanent value. If the conditions of the trade should warrant the continuation of operations during reconstruction, it is only fair that operation should bear the cost of these temporary expedients, constructing them under repair and renewal orders, the cost being eventually absorbed by the operating accounts.

Dept. of Metallurgical Engineering,
University of Cincinnati,
Cincinnati, Ohio.

Dedication of New Technology Buildings.—The new Massachusetts Institute of Technology at Cambridge, Mass., will be dedicated on Wednesday, June 14, during the big reunion which takes place June 12 to 14. The dedication will be held in the great court of the new buildings. Inspection of the new buildings will be on Monday, June 12, when members of the Technology Regiment will act as guides for alumni and their friends who visit the buildings. The public are invited to inspect the new buildings on June 15, 16 and 17 and see the exhibit "Fifty Years of Technology."

Synopsis of Recent Chemical and Metallurgical Literature

Chemical Engineering

Potash in Banana Stalks.—In the course of an examination of the banana stalk for paper making, it was found that the stalk contained potash. In the *Journal Soc. Chem. Ind.*, April 29, 1916, R. H. Ellis gives the following composition of the stalk.

	Ellis	Hanley
Moisture in original stalk, per cent.....	91.6	92.7
Dried matter in original stalk, per cent.....	8.4	7.3
Ash in original stalk, per cent.....	2.4	1.5
Potash in original stalk, per cent.....	1.14	0.9
Ash in dried matter, per cent.....	29.9	20.5
Potash in dried matter, per cent.....	13.73	12.35
Potash in ash, per cent.....	45.9	59.1

Dr. Hanley also extracted the juice by pressure in a small meat press, and found it to contain 0.7 per cent potash. From the above figures it will be noted that the dried matter is as rich in potash as kainit. Thus, from the figures, 1 ton of banana stalks will yield 188 lb. of dried matter containing 13.7 per cent of potash (K_2O), or 54 lb. of ash containing 47.5 per cent potash, or 25 lb. of pure potash. When stripped they have an average weight of 4 lb. each or 16,000 lb. in all, representing 1340 lb. (about 12 cwt.) of dried matter as rich in potash as kainit.

Substitute for Sodium Sulphide in Leather Industries.—A common method of unhairing hides and skins is by means of sodium sulphide in conjunction with milk of lime. Some experiments on the use of a substitute are described by J. E. PICKLES in the *Journal Soc. Chemical Industry*, April 29, 1916. About 1860 the use of a mixture of sulphur with lime and sodium carbonate was proposed by Lufkin, and used in the United States with some success. A series of experiments was made with these materials. When sodium sulphide is dissolved in water it is hydrolyzed with the formation of sodium sulphhydrate and hydroxide, and it has been proved that the sulphhydrate is the active depilatory agent, the caustic soda serving to swell the hide fibres: 78 parts of sodium sulphide produce 33 parts of sulphydron, SH (neglecting the weight of the sodium), and 40 parts of caustic soda. If sulphur is boiled with milk of lime, a certain amount of calcium sulphhydrate is formed, together with some polysulphides, the latter being not detrimental, if not actually advantageous, to the process. As the results of the experiments, it was found that if $\frac{1}{2}$ lb. sulphur is boiled with lime, the same unhairing effect is obtained as with 1 lb. of sodium sulphide or 3 lb. of $Na_2S_9H_2O$ ordinarily used. To obtain the same amount of caustic soda in the lime, as if the sulphide had been actually used, is of course a simple matter, since if sodium carbonate is added to the lime water calcium carbonate and sodium hydroxide are produced; roughly 11 oz. of anhydrous sodium carbonate or 33 oz. of soda crystals will give the same amount of caustic soda that is obtained from 1 lb. of sodium sulphide or 3 lb. of $Na_2S_9H_2O$.

The procedure is as follows: the calculated amounts of sulphur and of sodium carbonate are weighed, the sulphur is added to the lime when slaking, and if necessary boiled with the lime until all sulphur is dissolved. This gives a yellow liquid. The soda can be added during or after the slaking. This lime has been used in the experimental tannery of the University of Leeds on two packs of calfskins for chrome tanning, using sulphur and soda calculated to replace 5 per cent of sodium sulphide on weight of lime; the goods were ready for unhairing in four days, and as far as could be seen there was no difference between these skins and skins unhairied with sodium sulphide. The lime was also used on

one pack of hides for chrome sole leather. In this case more soda was added to the lime in order to increase the swelling. The hides were unhairied in four days. It has also been used for skins intended for vegetable tanned dressing leathers with equally good results. From these experiments it seems that these two materials would be a good substitute for sodium sulphide, with the advantage that the swelling can be controlled by increasing or decreasing the amount of soda, if more or less swelling is required than is given by sodium sulphide alone. By the omission of the soda an effect very similar to that of an "arsenic lime" is obtained.

Water Powers

Waterpower Laws in South and Central America.—The laws and regulations governing the use of water in Pan-American countries other than the United States have acted as a hindrance to the development of hydroelectric power, the same as in this country. A review of the laws of these countries together with the United States laws is given in an article by ROME G. BROWN, in the *General Electric Review*, May, 1916. The author states that the cause of the uneconomic waste in all the countries in question is that legislation for the regulation and use of water resources, instead of promoting their use, has become an obstacle to their use. Legislation has not kept pace with the progress in the science of water-power development and use.

The author gives first an account of the general sources of the laws and shows that they are all based on Spanish and French codes except the U. S., which is based on English law. He says "these different European sources of our American law of waters should be kept in mind in making any statement of the law of Pan-American countries. In the United States there is the greatest actual development, and also the greatest waste of water resources. There is also in that country the greatest amount of law and legislation with reference to water rights and at the same time the greatest lack of consistency or sanity in such legislation." He then gives a long discussion of the United States laws explaining the different powers of the Federal Government and the States in the matter of water power regulation, and showing how they have been obstacles in proper development. He says the present demand is for large power sites and that capital is waiting for proper protection.

The law in Spanish-American countries is then explained. In none of the countries of Spanish-America are the laws formulated in such a way as to attract private investment.

In Argentina the Federal power is, as in the United States, limited to the power to regulate commerce, and that is, with respect to streams, to regulate and protect navigation; but rivers are held to be the public property of the States. The uses of water by private parties are regulated by administrative authority under rules which may be modified or repealed. The enjoyment, therefore, of the use of waters is uncertain, and the rights of investors, even under authoritative permits, are precarious.

In Chile all rivers are "national property of public use." The use of public waters for power and other purposes is acquired by administrative concession. In 1907 a special statute was promulgated covering the subject of the "utilization of running waters for power." Under this statute the riparian owner may make a reasonable use of the waters which flow through his land. This right of use is not protected by law against a subsequent law, and the user is subject to certain regulations. The obstacles to development are uncertainty of tenure and possibility of burdens.

In Columbia the law is quite similar to that in Chile. In Cuba and Porto Rico rivers are part of the public domain and riparian owners have no rights except such as have been duly acquired under concessions legally made, or by prescriptive use. The laws have been codified and present a fairly reasonable certainty as to the terms upon which an investor may obtain a concession and operate under it. The laws appear to be more protective than most of the other countries under discussion.

In Uruguay the reservation of the right of the government to issue permits is not sufficient to encourage water power development; for the terms are subject to change, and insufficient protection is afforded against changes in the conditions of the authorization.

In Venezuela the public rights of navigation are made paramount, as in the United States. By a new constitution of 1914, the Federal Government now has control and investments are subject to changing legislation of the National Congress.

In Brazil, the general law is similar to that of Argentina. The Government is authorized to promote hydro-electric development for "federal" services, any excess to be sold for private use.

In Mexico the terms of concession, by which rights are obtained are too largely in the hands of the executive and subject to his caprice. Even under a stable government, the peculiarities of the Mexican law prohibit investment and development.

"The universal fault with existing policies of legislation, in these matters, is that the prospective investor, asking for a grant, concession, or permit, is viewed as one asking, for his own private benefit, a gift from the public. The theory is too much prevalent that, because water resources are a natural resource, they are, for that very reason, a purely public resource, and not by nature or in law for development in any other way than through the direct supervision of public authorities and for the exclusive and direct benefit of the public at large." Experience has demonstrated that utilization of wasting water powers cannot be accomplished by their development by the public authorities; but only through the capital of private investors. Such investors, however, rightly demand that security for their investment which shall afford to them reasonable protection against confiscation and loss of their investment, and against failure to receive fair returns thereon.

Recent Chemical and Metallurgical Patents

Iron and Steel

Nickel-Chromium Steel.—A special steel patented by JAMES CHURCHWARD, of Mount Vernon N. Y., and assigned to the Churchward International Steel Co., of New York City, has the following composition:

Steel, approximately	93.40%
Nickel, approximately	3.50%
Chromium, approximately	2.00%
Vanadium, approximately	0.35%
Manganese, approximately	0.50%
Silicon, approximately	0.25%

The steel contains approximately 0.10 to 1.00 per cent carbon. In manufacturing the alloy the metals themselves may be used or use may be made of ferro-alloys. Silicon is preferably mixed in the form of metal. The vanadium drives out occluded gases and also imparts elasticity when present up to 0.75 per cent. The silicon furnishes homogeneity and fineness of grain. The alloy is stated to be useful for deck plates for war vessels, and may be used as armor plate. Other uses are in shafting, and in general where resistance to impact,

shock and vibration are required. (1,181,570, May 2, 1916.)

Chloride Electrolysis

Caustic Soda and Chlorine Cell.—An electrolytic diaphragm cell with several interesting features is patented by HOWARD M. DuBOIS of Detroit, Mich. It is assigned to Pennsylvania Salt Manufacturing Company (compare cell patented by Arthur E. Gibbs and described in our issue of May 1, 1916, page 540). The cell can best be explained by reference to the sectional illustrations

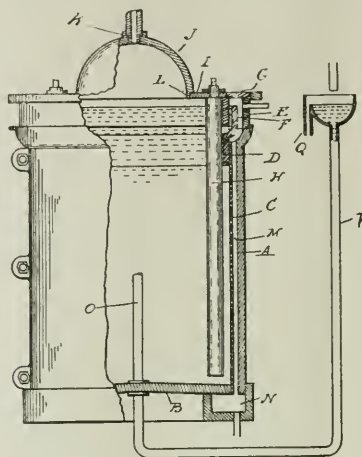


FIG. 1. SECTIONAL ELEVATION OF CELL

shown in Figs. 1 and 2. The outer casing *A* is composed of segmental metallic plates bolted together and forms the cathode. *B* is a non-metallic head at the bottom of the cell. The diaphragm *C* is cylindrical and is made of asbestos. *D*, *E* and *F* are rings of insulating material which form a trap above the diaphragm to allow the anode liquor to flow down between the diaphragm and cathode and prevent the hydrogen gas from entering the anode space. The dome-shaped member, *J*, serves to collect the chlorine and prevent any disruption of the anode from explosions. On account of the dome

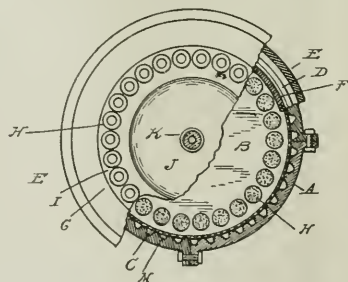


FIG. 2. SECTIONAL PLAN VIEW OF CELL

being the least resistant element of the cell to pressure, it will simply blow off in case of an explosion. The anode *H* is formed of a series of carbons arranged around the cell inside the diaphragm. The electrolyte is introduced through pipe *O*, and the proper level is kept in the cell by the hydrostatic column *P*. The inner side of the casing *A* is provided with grooves *M* (see Fig.

2), which form channels connecting the upper ends of the cell with a channel *N* at the lower end. These grooves greatly increase the cathode surface. The flow of electrolyte is continuous, and the caustic formed is drawn off at *N*. Hypochlorites are converted back to chloride by the action of the hydrogen in the overflow space before they can injure the cathode. (1,178,501, April 11, 1916.)

Electrolytic Cell for Nickel Extraction.—An electrolytic diaphragm cell is patented by FLOYD J. METZGER of New York City (one-third assigned to Hal. T. Beans and one-third to M. C. Whitaker of New York City). The cell is shown in cross-section in Fig. 3. Any suitable containing vessel 1 is used with carbon anodes 2, 2. The cell is described in connection with nickel extraction, and 3 represents a nickel cathode. The diaphragm 4 is of seasoned birchwood, formed by milling tools into a cup. The walls are about $\frac{1}{8}$ to $\frac{1}{4}$ in. thick, and the grain runs lengthwise of the sides, so that the end of the grain is presented at the bottom. This is done to prevent resistance to the current, and the current efficiency is high with the grain cut in this manner. In connection with nickel extraction a solution of nickel chloride, sp. gr. 1.3, made by treating a nickel ore with hydrochloric acid, was electrolyzed. The diaphragm keeps the chlorine formed at the anode away from the deposited nickel, while at the same time allowing the electrolyte to pass through. In one test a deposit of

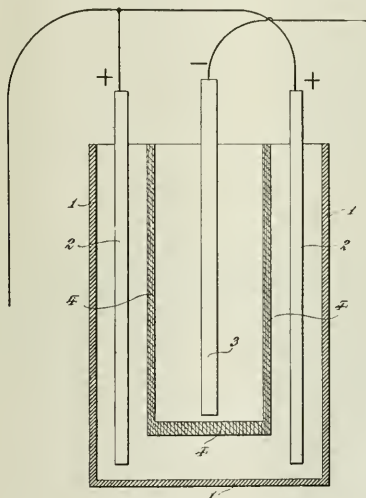


FIG. 3. CROSS-SECTION OF DIAPHRAGM CELL

33 gr. of nickel was obtained in three hours with a current of from 10 to 10.5 amp. and about 4.5 volts. The cathode surface was about 15 sq. in. (1,178,591, April 11, 1916.)

Hypochlorite Cell.—In a patent of J. F. WEBB, of Battersea, London, and WILLIAM WILLIAMS of Enham, England, an apparatus is described for the production of sodium or magnesium hypochlorite from chlorides of these metals. The cell consists of a receptacle for holding the solution, anodes of greatly compressed Acheson graphite, and cathodes of either the same material or of a suitable metal. The anode and cathode are separated by a plate of slate or porcelain. In order to isolate the hydrogen evolved at the cathode from the bulk of the electrolyte, orifices are made in the cathode and

deflectors are placed in these orifices. Referring to Fig. 4, which is a sectional elevation of the cell, the anode is shown at *d* and the cathode at *e*. The operating partition is shown at *f*. Above anode *d* a section, *d'*, of non-conducting material is placed to prevent the dispersion of the gases evolved at the electrodes. The deflectors

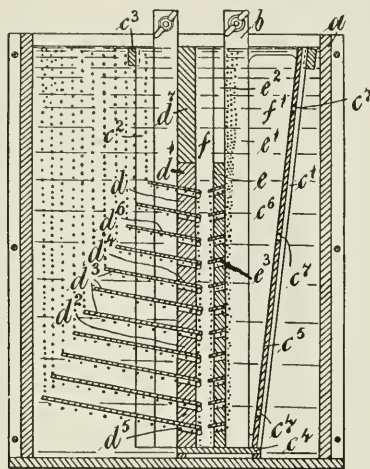


FIG. 4. HYPOCHLORITE CELL

d' and *e'* are placed in orifices in the anode and cathode respectively, and conduct the hydrogen from the cathode to the other side of the cathode from which it is generated, and it passes off at the top as indicated by the dots. The plates *c'* is provided to close up the cathode chamber.

The oxygen from the anode is used to keep the solution in circulation, and passes along the deflectors as shown. (1,175,572, March 14, 1916.)

Copper

Electroplating With Copper.—A method of depositing copper which is designed to reduce the time of obtaining the required deposit in plating is patented by S. C. BABCOCK, of Hamburg, N. Y., and E. W. HAGMAIER, of Lackawanna, N. Y. No special apparatus is required. The novel feature of the process consists in the use of a solution of copper sulphate, containing sulphuric acid, creosote, phenol, cryslyl hydrate or cresylol, phlorol, and gaicol. The addition of these phenolic homologues causes a harder and firmer deposition and causes the copper to deposit in the smallest indentations. The bath is made up in the usual way, having about 270 pounds of copper sulphate dissolved in about 240 gallons of water. To this is added about 49 ounces of phenol sulfonic acid, properly prepared so that the phenol is thoroughly combined with the sulphuric acid. The voltage is between three and four volts and the current is about 750 amperes to a 140-gallon tank. The current density is somewhat variable, and can be varied depending upon the acidity of the solution. Operation and test of these improvements are claimed to show a time-reduction over previously known methods of about fifty per cent, and as above stated, the deposition is much more perfect and of greater density. The method is applicable to making halftones, electrotypes, in covering wires for electrical conductors, and for lining tanks and pipes with copper. (1,174,466, March 7, 1916.)

Zinc

The extraction of zinc from its ores by means of a solution of SO_2 is patented by HENRY T. DURANT, of London, England. The flow-sheet of the process is given in Fig. 5. Oxidized or carbonate ores of zinc are directly amenable to the process, but sulphide ores must first be roasted to oxide or sulphate. The sulphurous gases from the roasting operation are used as a solution of sulphurous acid to extract zinc from the ore. The

nion. The charge is introduced through a manhole. After the charge has been blown for a certain period, the converter may be rotated or oscillated to break up the charge and allow it to settle again on the grate in a new position, after which another period of blowing ensues. (1,172,321, Feb. 22, 1916.)

Treatment of Leady or Irony Zinc Ores.—For the production of cleaner spelter from zinc ores containing considerable iron or lead, or both, CHARLES A. H.

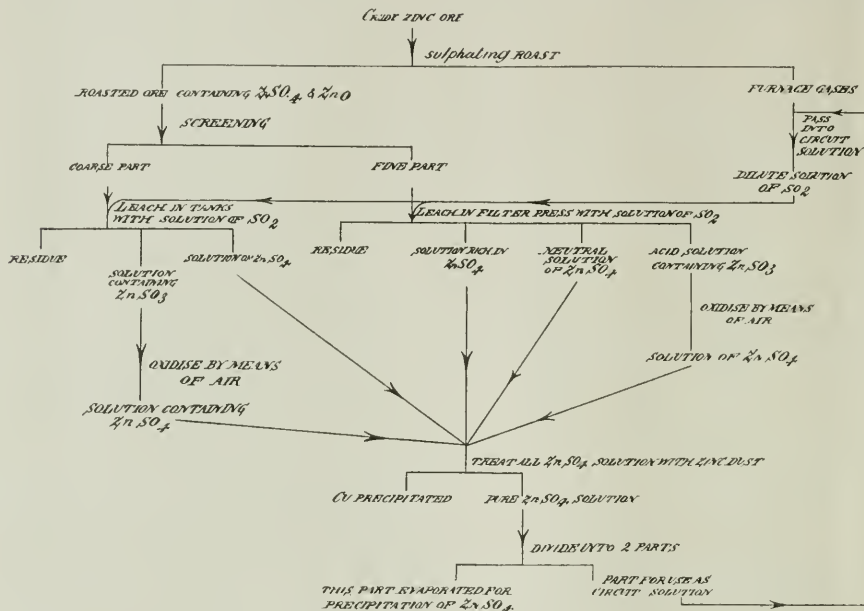


FIG. 5 PROCESS OF EXTRACTING ZINC FROM ORES

present patent covers improvements on the process previously disclosed. The ore is roasted to contain as large a percentage of sulphate as possible and the operation is preferably conducted in a reverberatory furnace. The gases are absorbed in circuit solution which is used to extract metal from the ore. The finely divided material is treated in filter presses while the coarse is leached in vats. The first solutions obtained will be rich in zinc sulphate, but the last may contain mainly sulphite, which will have to be oxidized by means of air. Copper contained in the solution is removed by precipitation with zinc dust. The recovery of zinc is effected as zinc oxide by evaporation of part of the solution, while the balance is diluted with wash solutions and returned to the absorption tower and then to the leaching vats or filter presses. (1,180,765, April 25, 1916.)

Production of Zinc Oxide.—An improvement in the method of "blowing" zinc ores mixed with fuel for the production of zinc oxide is claimed in a patent granted to FRIEDRICH C. W. TIMM, of Hamburg, Germany. The object of his invention is to provide means whereby the mixture under treatment may be kept in a physically homogeneous state, so that cracks and blowholes will not occur. He therefore makes use of a spherical converter mounted on hollow trunnions through one of which the air is blown, while the other forms an exit for the zinc oxide. The converter has a grate which is normally at the bottom of the converter, and beneath which the air is supplied by a connection with the trun-

DESALLES, of New York City, has patented a special method of charging the retort. He first charges the impure ore in a loose or briquetted condition into the back of the retort, and closes the charge with a briquet of fuel and pure zinc ore containing little or none of the impurities which it is desirable to prevent passing into the spelter. The front briquet is not subject to the high temperature that prevails at the back of the retort, so that the front charge serves as a filter or condenser which collects the impurities. (1,166,447, Jan. 4, 1916.)

Proper Care in Use of Crucibles in Foundries

The securing of the proper clays in sufficient quantities has troubled the crucible maker greatly since the beginning of the war, and made it impossible to supply the highest grade crucibles. Better clays, however, are being secured at present and with their use better results will be had in the foundry and longer lived crucibles will result.

It rests, however, with the user, in a measure to improve the present unfortunate state of affairs and this can be done in the following ways:

Greater care must be given in annealing—more time must be consumed, after the crucible is received, before it is put into service, and smaller crucibles used than those which the foundry has been in the habit of using. In past years all brass rolling mills, crucible steel casters and jobbing shops thought nothing of having six

months or a year's stock of crucibles ahead of their wants—seasoning and drying. To-day, a crucible is put into active service as soon as it is received.

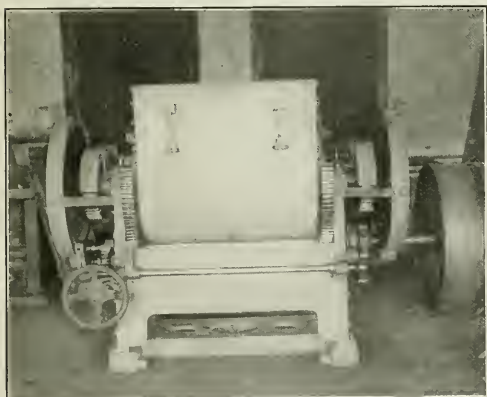
The native clays now used by the crucible maker have made the crucible more frail and tender than were those made from foreign clays—more likely to crack on sudden heating and cooling. Therefore, more than ordinary care must be used by the melters in the handling of American-clay-made crucibles.

Crucibles should not be cooled down too rapidly, any more than should the heating up be done too quickly. It is a good plan to return the crucible while it is still hot, after the day's work is done, to the furnace from which, of course, the coal has been dumped. By doing this, the strain in the cooling will not be as severe and the crucible will not crack so early in its life.

The smaller the crucible is, the greater are the number of heats that can be secured. Therefore, if a crucible of a size or two smaller than that which is generally used is adapted, better values and less disappointments will be the result. For instance, if a foundry uses a No. 400 pot, it should adapt a No. 300 or a No. 225—or in a shop where No. 60's are the rule, a No. 45 or a No. 50 should be used. In this way both caster and crucible maker will be relieved of the hundreds of annoyances and complaints that have occurred in the last few months.

Mixer

The adjoining illustration shows one of the strongest heavy-mass mixers on the market to-day. The cast-iron cylinder section is provided with a jacket so that the charge of the mixer may either be artificially cooled by the use of brine or cold water in the jacket or may be heated by circulating steam or hot air. This machine is particularly adapted for the mixing of smokeless powders, such as cordite, lydit, or in fact for all classes of nitro-cellulose compounds. But this mixer is also well adapted for handling artificial silk, gutta percha, "electro mass," etc.



MIXER

The illustration shows a machine with a bowl capacity of 160 gallons. It has been so carefully designed that it is usually operated with less than 10 hp. All the gears are of high-carbon steel, machine-cut, while the bevel gears on the dumping mechanism are of nickel-steel and the worm wheel of bronze.

This mixer has been placed on the market by Mr. Paul O. Abbé, 30 Broad Street, New York City.

A Combination Boiler Meter

A boiler meter which is a combination of three separate meters in one casing each drawing its own record in a distinctive color on a 12" chart, is made by the Bailey Meter Co., Boston, Mass. This meter records

- (1) The rate of steam output from the boiler,
- (2) The rate of air flow through the furnace, and
- (3) The condition of the fuel bed.

It also correlates and compares these factors in such a simple manner that any fireman can readily understand the readings and be informed instantly of any needed change in the furnace or draft conditions to secure the best efficiency and maximum capacity. A photograph of an installation is shown in Fig. 1. Charts are shown in Fig. 2.

The steam flow is recorded by the red pen drawing a red record in the center section of the chart, the graduations being in per cent of the boiler's rated capacity on a uniform scale. This part of the meter is identical with the Bailey steam meter described in our April 15, 1916, issue. It operates upon the principal of measuring the pressure difference across a Monel metal orifice placed in a flange of the steam line.

The air flow is recorded by the blue pen drawing a blue record. This pen is located so that it travels immediately in front of and records just ahead of the steam flow. It is operated by the draft differential between the firebox and the uptake, but instead of reading in terms of draft it reads in terms of steam output. In other words, it gives the same reading and draws a coincident record with the steam flow so long as the right amount of air is used for combustion. If the air flow reads more than the steam flow it shows too much air and corresponds to low CO_2 ; if it reads less than the steam flow it means insufficient air and loss due to unburned gases. This is based upon the principle that air is a fuel just as much as coal is, and a certain evaporation should be obtained per pound of air. This standard is determined for each boiler and the meter adjusted accordingly.

The furnace indicator drawing a record on the outer section of the chart shows the conditions of the fuel bed. The fire is of the right thickness when this pen is on the shaded band, too thick when above, and too thin when below the band. This also is adjusted to individ-

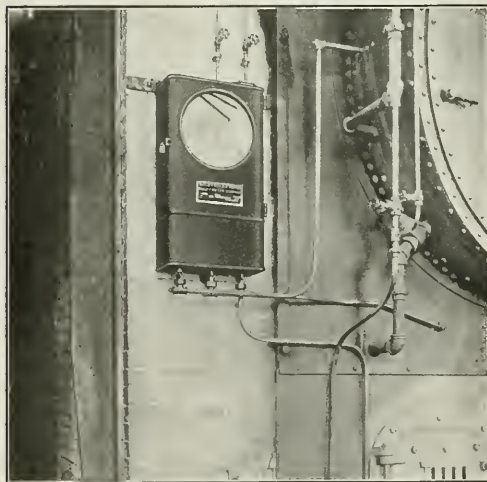


FIG. 1—METER INSTALLED IN BOILER ROOM

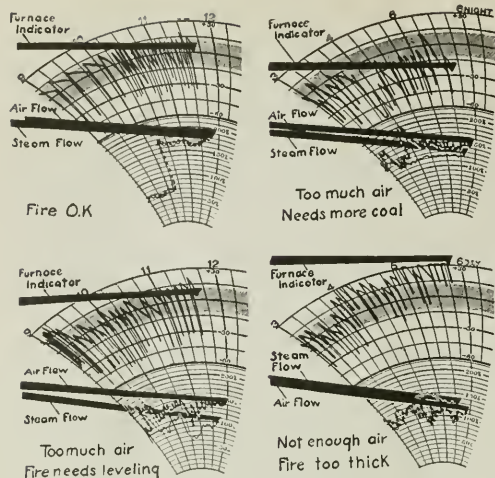


FIG. 2. ILLUSTRATIVE CHARTS

ual conditions after extensive tests have been made to determine the best kind of fire to carry. This furnace indicator is operated by draft pressures and is in reality a measure of the resistance of the fuel bed to the flow of air. It should not be confused with the drop in draft pressure across the fuel bed, for it includes the draft pressure in the uptake as well as the firebox and ash pit in such a way as to eliminate the effect due to the intensity of the draft or the rate of flow of air and responds only to changes in condition of the fuel bed. That is, the pen does not move when the damper opening or draft pressure varies from maximum to minimum unless the fire changes but when the fire burns too thin or develops holes, the recorder shows it regardless of the intensity of the draft.

Every part of the meter responds instantly to changes in any of the operating conditions. In a hand-fired furnace it plainly shows each opening of the fire door, cleaning of the fire, etc. When applied to stokers it brings out many very interesting points regarding the operation and control.

The meter is of very simple design and rugged construction.

Annual Meeting St. Louis Section, American Institute of Mining Engineers

The annual meeting of the St. Louis Section of the American Institute of Mining Engineers was held at St. Louis, Mo., May 20, 1916. There was an excellent attendance from all parts of the territory governed by the Section, members being present from the lead belt of Southeast Missouri, the Joplin zinc district, School of Mines at Rolla, Kansas City, and University of Illinois, Urbana. The day was devoted to trips to industrial plants and the evening to a dinner at which President L. D. Ricketts and Secretary Bradley Stoughton of the Institute were guests.

In the forenoon the party inspected the Koppers by-product coke ovens of the La Clede Gas Light Company in South St. Louis. The company manufactures gas for domestic and industrial use and recovers tar, ammonia and light oil from the distillate. These by-products are disposed of to local manufacturers who further refine them for various purposes.

A noon luncheon was held at the Mercantile Club,

after which a trip was made by special trolley cars to Granite City, Ill., where the plants of the National Stamping & Enameling Company and the Hoyt Metal Company were visited.

The annual banquet was held at the St. Louis Club and was followed by the business meeting and an address by President Ricketts. The following officers of the Section were elected for 1916-17: Chairman, Charles J. Adami; vice-chairmen, Herman Garlicks, Frank W. De Wolf and M. M. Valerius; secretary-treasurer, W. E. McCourt; members of executive committee, together with the foregoing, Albert W. Dickinson, Carroll R. Forbes, Charles T. Orr, F. D. Rash. The matter of inviting the Institute to hold a general meeting in St. Louis in 1917 was referred to the executive committee of the Section with power to act after consulting local operators and members to determine what support for the project would be forthcoming.

Dr. L. D. Ricketts addressed the Section on "The Present Conditions and Outlook of the Copper Industry in the West," and incidentally made reference to the copper industries of Chile, which he had recently visited. Beginning with the pioneer work in copper smelting done by Richard Pearce in Colorado, Dr. Ricketts traced the metallurgical development of the industry to the present time. The principal features of this development were the introduction of converting, first with acid and then with basic linings, the gradual enlargement of the reverberatory furnace, the beneficiation of very low-grade ores, the establishment of hydrometallurgy on a large scale, and finally the use of flotation. In the application of the latter process it has been found that its place in the metallurgical scheme depends on the ratio of concentration of the ore. For ratios of from 3:1 to 10:1, gravity concentration is called for as a preliminary process, with flotation as an accessory on slime and reground middlings and tailings. When the ratio rises to 25:1 or more, original fine grinding and flotation may become the primary process, followed by gravity concentration as a secondary process to recover coarse mineral which may have escaped flotation.

Referring to the future of the copper industry, Dr. Ricketts stated that the principal problems from a metallurgical point of view were the treatment of very low-grade sulphide and silicate ores, and the recovery of the valuable metallic and chemical constituents of smelter gases. An increased use of phosphate fertilizer will afford an outlet for the vast quantities of sulphuric acid which can be made from smelter fumes. In general the outlook for the copper industry is favorable, and with improvements in methods we may expect to be treating profitably ores containing as little as 0.75 per cent copper. Dr. Ricketts closed his remarks with a compliment to the local operators for their liberality in exchanging ideas and information, and showed the advantages that accrue from such a custom.

Copper Chemical Equipment.—Another indication of the present rapid progress of industrial chemistry in this country is the entry of the old and well-known copper-smith firm of August Roos' Son of 429 East Ninety-first Street, New York City, into the chemical engineering field. This firm is now equipped to design and construct distilling, evaporating, dissolving and extracting apparatus for the chemical and allied industries.

The Chemical Construction Company of Charlotte, N. C., has increased its capital stock from \$10,000 to \$50,000 owing to the rapid expansion of its business.

The Goldschmidt Detinning Company announces the removal of its offices to The Equitable Building, 120 Broadway, New York City.

Industrial Notes

Pig-Iron manufacturers in the Birmingham, Ala., district are sold up pretty well for the balance of the year, and in all probability a scarcity of iron in this district will become a reality. There are already a number of inquiries for 1917 delivery.

Sulphuric Acid in 1915.—The production of sulphuric acid in the U. S. in 1915 is given in a recent Geological Survey report by W. C. Phelan, as follows: 1,518,271 short tons of 50, 52, 53 and 55 deg. were produced. This compares with 1,628,402 short tons of these strengths in 1914. The production of 60 deg. acid was 657,076, which compares with 551,955 short tons in 1914. The production of 66 deg. was 1,019,024 short tons, which compares with 916,192 short tons in 1914. Of other strengths there was produced 189,795 short tons, comparing with 65,890 short tons in 1914.

The Kalbperry Corporation, New York, have opened a new office in the Metropolitan Building, 31 Union Square, West, for the purpose of conducting a chemical engineering business in investigation, design and operation. Besides the strictly chemical work the company will handle buildings and apparatus pertaining to same.

Possibilities of South Africa for Electrochemical Industries.—The development of resources committee of the South African Institute of Electrical Engineers has just issued a report on the possibilities of establishing certain electrochemical industries on a commercial basis in South Africa, according to Commerce Reports. In reviewing the document the *Board of Trade Journal* states: "The report does not attempt to cover the whole subject, but is confined to South Africa's chief industries, agriculture and mining. These industries, taken together, now require annually more than £2,000,000 (\$9,733,000) worth of chemicals, all of which are imported in the form of fertilizers, cyanides, and nitrates. The essential elements for the successful manufacture of the compounds are cheap electricity, abundant coal and limestone, and all these, together with the necessary labor, are available in South Africa. Furthermore, the local market is to a considerable extent protected from competition by the necessarily high cost of transport for imported articles, as well as by the customs duties. The report proceeds to consider the prospects of producing calcium carbide and cyanamide and derivatives of cyanamide, and the conclusion is reached that these products can be profitably manufactured in South Africa provided the necessary raw materials are available at reasonable cost. It is therefore urged that an early investigation should be undertaken with regard to the location, quality and cost of production of these raw materials." It is reported that a factory has been established at Vryheid (Natal) for the production of ammonium sulphate. Plant, stated to be capable of making 5000 tons annually, has been laid down at a cost of £350,000 (\$1,703,275).

The Richardson-Phenix Co., Milwaukee, Wis., has issued Bulletin No. 5, April, 1916, describing oil filters in standard sizes of 1 to 800 gallons hourly filtering capacity. The catalog is devoted principally to a description of Richardson-Phenix Multiple Type oil filters having capacities of 1 to 35 gallons per hour.

The Castner-Kellner Alkali Company and Brunner, Mond & Co., of England, are effecting a consolidation of their interests in order to meet foreign competition after the war. The combined capital will be about \$42,500,000.

The Viscose Fibre Co. is planning a large addition to its plant at Marcus Hook, Pa.

Regulation of Electrotyping Solutions.—The second

edition of circular 52 has been prepared by the Bureau of Standards. It has been entirely rewritten, the additional sections being devoted principally to a discussion of the effect of various factors upon the deposition of copper in electrotyping baths, based upon the literature on this subject, and upon recent investigations by the Bureau of Standards. The limits of composition of solutions, temperature and current density are defined within which copper having the required tensile strength and ductility may be obtained. The circular also includes conversion tables for Fahrenheit and Centigrade temperatures, metric and customary units, and specific gravity and degrees Baumé. Definitions of important electrical terms are given, and also tables showing the weight and thickness of copper deposited by a given current in a specified time.

The Robeson Process Company, which recovers products from waste solutions of paper mills is increasing its production by the installation of a plant at Covington, Va. It is installing an evaporating plant recently completed in the shops of the Swenson Evaporator Company. This is a quadruple effect of a type very similar to that used for evaporating sugar solutions.

Alcohol from Waste Sulphite Liquor.—On account of the present war prices of alcohol, one of the sources of raw material being investigated is the waste sulphite liquor from the paper mills. The Kimberly-Clark Paper Company, Neenah, Wis., has installed a preliminary plant for alcohol production under the Marchand process with the apparent purpose of increasing its proportions if satisfactory. It seems that this process promises very much higher yield of alcohol per ton of waste than has hitherto been obtained. It is claimed that the chemical means used bring about results which were not believed possible. Mr. Charles Marchand will be recalled by some people from his work on peroxide. Briefly the alcohol process includes chemical treatment of sulphite liquor, reduction of its volume by concentration in the standard Swenson evaporator, and subsequent distillation by the ordinary known processes.

Research into the Development of Canada's Natural Resources

Mr. Arthur D. Little of Boston, Mass., and the organization of Arthur D. Little, Inc., have been retained by Lord Shaughnessy, president of the Canadian Pacific Railway Co., to assist in carrying out extended plans for a scientific research of Canada's natural resources. While there has been a considerable development, only a small part of Canada's resources has been really exploited, and, aside from the investigation of the country's resources by the government departments, it has been fragmentary.

It is Lord Shaughnessy's belief that with properly guided research the opportunities afforded by the natural resources of Canada can be demonstrated so as to interest capital and bring about a great industrial development, and it is for this work that Mr. Little has been retained.

In order to provide proper facilities for this work, a Dominion charter has been taken out for Arthur D. Little, Limited, and offices have been fitted up in Montreal.

The H. M. Lane Co., Detroit, Mich., are preparing plans for a continuous malleable foundry for the Timken-Detroit Axle Co. This plant will be located in Canton, Ohio. It is planned to arrange to handle the product with greatest efficiency so as to reduce labor and improve quality.

Personal

Messrs. Clarence L. Burger and W. H. Crichton Clarke, formerly associated with the late Edward B. Moore, former commissioner of patents, in the firm of Moore & Clark, announce that they have associated themselves together under the firm name of Burger & Clarke, and will continue in the offices of Mr. Burger, 2 Rector Street, specializing in the law of patents, trademarks, and copyrights, including the soliciting of United States and foreign patents.

Mr. Charles A. Chase of Denver is reported to have suffered a broken wrist and minor injuries as the result of an automobile accident in Bummer's Gulch, Boulder County, Col. Mr. Chase was on his way to the tungsten district when the accident occurred due to failure of the brakes to hold on a steep hill.

Mr. Hardy S. Ferguson of New York City is engineer in charge of the erection of new pulp mills for the St. Maurice Paper Company, near Three Rivers, Quebec. This is to include both sulphite and sulphate mills of considerable capacity. These installations are expected to be representative of the most recent ideas and developments and will in every respect be thoroughly standardized as to their general layout and the general design of their equipment. Mr. P. B. Sadtler of Chicago, who has been awarded contracts for the evaporating equipment, is of the opinion that this mill will not be closed to the public for purposes of secreting technical facts.

Mr. J. R. Finlay was selected to deliver the address to the graduating class of the Colorado School of Mines on May 26.

Mr. Charles L. Foster, formerly manager of the Akron district for the Westinghouse Electric & Manufacturing Company, has taken charge of the sales department of the Electric Furnace Company of Alliance, Ohio, under the title, manager of sales. Mr. Foster has had a long experience in the electrical line, having been for thirteen years with the Westinghouse Company.

Prof. E. C. Franklin of Leland Stanford, Jr., University, has had an unfortunate laboratory accident, through an explosion in his laboratory, which caused burns and other injuries. Later news are more reassuring, and the fact is announced that Professor Franklin is steadily recovering in the hospital, and that the accident will not leave serious consequences.

Mr. H. S. Kimball has been elected president of the Aetna Explosives Company, Inc., succeeding A. J. Moxham, who becomes chairman of the board. Mr. Kimball is also president of the American Zinc, Lead & Smelting Co.

Dr. A. D. Little has been appointed head of the bureau which was recently organized in Montreal, Canada, to co-ordinate the work of scientific research in Canada.

Dr. Ralph H. McKee has resigned as professor of chemistry at the University of Maine and will take charge of the research department of the Tennessee Copper Co., with laboratory at Ridgefield Park, N. J.

Mr. D. T. MacLeod has opened an office at 50 Pine Street, New York, as consulting engineer in the design and construction of by-product coke-ovens. Mr. MacLeod was formerly chief engineer of the United Coke & Gas Co., American Coke & Gas Construction Co., and Otto Coking Co.

Mr. Philip Schmitt, formerly superintendent of electric furnaces at the United Steel Co., Canton, Ohio, is now in charge of a new Héroult installation at the Harrow Spring Co., Kalamazoo, Mich.

Dr. Joseph Struthers, formerly secretary of the American Institute of Mining Engineers has been appointed treasurer of the Federal Export Corporation, which is affiliated with the Federal Shipping Co., Inc.

Mr. A. W. Taylor, formerly superintendent of the open-hearth department of the Gulf States Steel Co., Gadsden, Ala., has been appointed metallurgist with the Jones & Laughlin Steel Co., Pittsburgh, Pa.

Mr. Wilbur S. Wilding has been appointed eastern manager of the International Filter Co., Chicago, with offices in the Woolworth Building.

Mr. George J. Young has been elected professor of metallurgy at the Colorado School of Mines, beginning September, 1916. Mr. Young was formerly director of the Mackay School of Mines, Reno, Nev., and lately professor of mining at the University of Minnesota.

Book Reviews

The Canadian Mining Manual—1915. Edited by Reginald E. Hore, editor of the *Canadian Mining Journal*. Price, \$2.00. Toronto: The Canadian Mining Journal.

This annual contains statistical and descriptive data relative to the mining industry of Canada, and is designed to furnish reliable information to those who may be interested but not well informed on the subject. The work is a compilation from many sources. The statistics given are final for 1914 and estimated for 1915. The first chapter is devoted to a general review of progress and conditions in 1915, the various metallic and non-metallic products being considered in alphabetical order. This is followed by a review according to Provinces. The mining companies operating in Canada are then listed alphabetically, giving data on property, plant and personnel of staff. In the last division of the book the operating companies are listed according to product. The manual is a useful work of reference on the Canadian mining industry.

The Flotation Process. Compiled and edited by T. A. Rickard. 364 pages, 79 illustrations. Price \$2.00. San Francisco: The Mining & Scientific Press.

This is a compilation by the editor of *Mining & Scientific Press* of articles on the subject of flotation that have appeared in that magazine during the past few months. As the editor states in his preface, the book "has been prepared to meet the need of the hour," supplementing the information contained in earlier editions of Hoover's work on the subject.

The first paper is by the editor, giving a general inclosures of patentees of the process. In the subsequent papers, various authors attempt to elaborate the introduction to the subject and covering its history, physics and methods of application as revealed in the ories of flotation with a view to developing a scientific method of study and procedure. Since the several contributors approach the subject from different points of view, it is inevitable that some of their suggestions are not wholly in accord and that apparent contradictions confront the reader as he passes from one article to another.

Some of the papers relate more strictly to the commercial application and results of the flotation process; among these one of the most important is the contribution by Messrs. Butters and Clennell on the cyanidation of flotation concentrates.

The experimenter will be interested in Mr. Ralston's description of methods and machines for testing ores by flotation. This paper covers a great variety of devices for floating ores, and will be of value to the student or to those engaged in systematic testing.

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The Semi-Annual Index

As long as this journal was a monthly, the twelve is-
sues of a year comprised one volume. The change to
a semi-monthly has made it necessary to divide a year's
contents into two volumes in order to keep the size of a
volume within reasonable limits, and an alphabetical in-
dex will be published with the last number of each vol-
ume. Accordingly the present issue concludes our four-
teenth volume and bound into this issue will be found
our first semi-annual index.

The Slump in Tungsten

The inevitable slump in the tungsten market has come.
It came quickly, and apparently to the surprise of those
most concerned, viz., the small producers who naturally
were the optimists and perhaps blinded to or ignorant
of the economic situation. Outsiders generally had re-
garded the tungsten market as the most precarious of
the metal markets that had been stimulated by the
war.

Never before had the tungsten business been so
profitable; always it had been erratic, experiencing first
a fat season and then a lean one. With the sudden de-
mand created by the war, prices soared to unexpected
heights, and while at first producers could scarcely be-
lieve their good fortune, they later seemed to become
inoculated with the idea that prices would go still
higher and hold for a year or more.

The slump resulted primarily from natural causes—
the development of an adequate supply from new and
obscure or dormant sources, brought forth by attrac-
tive prices. It took some time to stimulate that supply,
but when it became visible it loomed suddenly large.
Boulder County, Colorado, had been regarded, and
justly so, as the principal tungsten field in this country,
for in 1913 it produced the equivalent of 953 tons of
60 per cent WO_3 concentrate, which was 62 per cent of
the total domestic output and perhaps 12 per cent of
the world's production. In 1914, however, first rank
was taken by the Atolia field in the Mohave Desert of
California, and Boulder dropped to second place with
an output of only 467 tons, or 47 per cent of the domes-
tic output. The year 1914 was not particularly favor-
able for tungsten production, which probably accounts
for Boulder's loss of prestige. In the early part of the
year prices were low, ranging around \$6.50 per unit for
60 per cent WO_3 concentrate. The outbreak of the war
first paralyzed and later stimulated the market until
toward the close of the year the price rose to \$9 per
unit, which was a highly profitable figure.

It was not until late in 1915 and early in 1916, how-
ever, that the boom prices became manifest. In
Boulder County they rose rapidly to as high as \$90

per unit, though a story of mine promotion and stock jobbing is said to have been connected with that fancy price. At all events, \$75 per unit was realized for large quantities of concentrate and producers became so optimistic as to have visions of a \$100 market. About two months ago one small producer actually refused \$82.50 per unit, holding for \$100; just lately he sold for \$20 and was glad to get it.

It is reasonable to assume that the possibilities of production from obscure sources were not appreciated in the larger districts of Boulder and Atolia; but the fact remains that from sporadic occurrences of tungsten ore in South Dakota, Utah, Arizona, New Mexico, Idaho, and parts of Colorado other than Boulder County, a considerable output was forthcoming. Imports also grew, shipments from South America and Japan swelling the domestic supply. The foreign product, moreover, was in some cases higher in grade than our own, and proportionately more desirable. The inevitable result was a satiated market.

The situation at the present writing is about this: With the exception of a few large producers who have their own eastern connections, independent operators are unable to market concentrates. Buyers say that there is a plentiful supply in the East, and while there is still a nominal market in the West, the producers have completely lost control of it. From \$75 per unit the nominal market has slumped rapidly to \$50, \$40, \$30 and even \$25 without arousing any eagerness to buy. A still further drop is anticipated among buyers until the level is reached at which imports will be unprofitable, especially under the ocean freight rates now prevailing. They look for a base price of perhaps \$12 to \$15 per unit, and think the market may be stabilized at that figure. But even such a market, if open and steady, would be a boon to the tungsten industry. As for the future of producers, it will be a case of the fittest surviving. Good mines served by modern concentrators will stay longest in the field; the adventitious operator with poor equipment must retire.

Production of War Steel

Statistics of the production of finished steel in the United Kingdom in 1915, just made public, suggest that the production of shell steel in England has not been as large as usually surmised, and our own production of this material, whether exported in finished or unfinished form, becomes relatively more important.

Unfortunately the British statistics lack precise details on this point. There is one item, "General merchant steel (not included under angles and girders, etc.)," given at 534,503 gross tons, while the general item of unenumerated products is given at 770,981 tons. Rolled steel rounds must be included in the one category or the other and thus cannot have amounted to a large tonnage, particularly when it is observed that the exports of "steel bars, etc." in 1915 amounted to 489,464 tons, of which 349,297 tons was for France, that for France being undoubtedly shell steel almost exclusively. Production of steel forgings, in the rough, is given at 118,102 tons. Apparently, therefore, the production of

steel for British conversion into shells can have amounted to only a few hundred thousand tons.

Exports of steel bars from the United States in 1915 amounted to 403,577 tons, the great bulk of this material being destined for conversion into shells in French machine shops. Thus it would appear that France has been producing the preponderating quantity of shells, drawing shell steel from both England and the United States, and presumably having a fair steel production of her own.

There are no data available whereby the steel consumed in shell manufacture in the United States can be estimated. The value of finished but not loaded shells exported in 1915 was about \$50,000,000, while the value of loaded shells exported seems to have exceeded \$75,000,000. When the statistics of steel bar production in the United States become available it may be possible to make an estimate of the tonnage, by observing the extent to which the proportion of steel bars produced is above normal.

It is quite erroneous to assume, therefore, that the British steel industry is engaged very largely in the manufacture of ammunition, and that orders coming to this country simply represent small additional requirements. The British steel industry, however, is as busy as it can be when it suffers more or less from a shortage in labor. While the production of steel rounds, as indicated, has been rather small, measured only by hundreds of thousands of tons, the total production of finished rolled steel, including pipes and tubes, etc., amounted in 1915 to 6,325,844 tons. That compares with a production of 8,350,944 tons of steel ingots and 8,793,659 tons of pig iron. The ingot and finished steel figures agree well, showing a loss in weight of 23 per cent from ingot to merchantable production, while American statistics have for years run at about 24 per cent. The relation between steel and pig iron, however, is quite unusual, for the steel ingot production was easily the largest on record, whereas the pig iron production fell far short of that in many previous years. In 1913 there were produced 10,481,917 tons of pig iron and 7,663,867 tons of steel ingots, against 8,793,659 tons pig and 8,350,944 tons steel. Thus the excess of pig iron over steel ingots was reduced from 2,818,050 tons to 442,715 tons, while the proportion of steel to pig iron rose from 73.1 per cent to 95.0 per cent. A part of the decrease in pig iron is to be accounted for by a decrease in exports from 1,124,181 tons to 611,617 tons and a small part to a reduction in stocks, while the remainder is to be attributed to a reduction in the production of iron castings.

If the British production of shell steel was smaller than might have been assumed, the production of ship steel was enormous, as suggested by the following statistics of production:

Gross tons—1915

Plates, $\frac{1}{8}$ in. and thicker.....	1,367,577
Angles, tees, channels and sections.....	762,717
Girders, joists and beams.....	343,617
Total	2,473,911

As the exports of such material were only 205,163 tons (against 254,947 tons in 1913) and as there can certainly have been no large use of plates and structural material for ordinary purposes it is quite evident that the great bulk of the material indicated above, probably almost 2,000,000 tons, was for the construction of ships.

Thus it is seen that in the case of England the demand for steel created by the war is much larger for building ships than for making shells. The export demand upon the United States has reflected heavy requirements in steel other than for making shells, conspicuous lines being rails, railway rolling stock and automobiles, particularly what are commonly called "trucks." They appear in the official export statistics as "commercial automobiles," a designation that has somewhat run amuck, by the way, considering the use to which they are put.

Madison, Wisconsin

It is purely a coincidence, but a happy coincidence, that three articles in this issue have emanated from Madison, Wis. Dr. Oliver P. Watts of the University of Wisconsin describes an elaborate electric arc furnace designed for laboratory use on page 681. Mr. Oliver W. Storey of the C. F. Burgess Laboratories deals with the theory and practice of the sherardizing process on page 683. Mr. Henry E. Surface of the Forest Products Laboratory discusses the use of wood waste as pulpwood on page 701. Here we have three distinct Madison centers of research represented—a state institution, a private institution, and a federal institution respectively—independent of each other and each with its own sphere of influence, yet correlated and thereby indicating in a pretty manner the catching character of the research spirit. In these days when the national organization of research and the creation of new nuclei of research in the United States has become an urgent matter, it is pleasant to be reminded of how much has already been accomplished. And when those American cities are counted, in which a true spirit of research has been liveliest and most active at an early date, Madison, Wis., is among those in the front rank.

Physical Chemistry of Assaying and Cupellation

From a technical standpoint, any industrial chemical or metallurgical process is in the end applied physical chemistry. We don't mean that physical chemistry is all that is required. Mr. Maximilian Toch is probably quite right in saying that "chemical engineering is 49 per cent chemistry and 51 per cent business acumen." What we mean is that his 49 per cent chemistry must be applied physical chemistry—not pure chemistry. Nor do we want to raise the question as to what is more important in applied physical chemistry—the foundation supplied by the physical chemist or the superstructure raised on it by the engineer. Our claim is that to produce industrially sound results, a combination between engineer and physical chemist, not engineer and pure chemist, is needed.

The development of the flotation process brings out this very point very clearly, as we tried to show in recent comments on the theory of flotation. But the flotation process is still considered by too many people as something of such an exceptional nature that it might require quite naturally exceptional measures. It is therefore pleasant to call attention to the article by Prof. Boyd Dudley, the first part of which appeared in our issue of June 1, while the concluding part is published in our present issue, as in this article it is clearly shown that a study of equilibrium conditions, according to well-known principles of physical chemistry, is required to understand the silver losses in such a simple every-day procedure as the fire assay of gold and silver ores by the crucible method. Indeed, the same fundamental principles of distribution equilibrium which Professor Dudley applies to the silver loss in the fire assay of gold and silver ores, apply to the slag loss of copper in matte smelting and the slag losses of lead and silver in lead smelting. The subject is therefore of decidedly more than theoretical interest.

In the fire assay of gold and silver ores equilibrium conditions are established in the crucible fusion. Professor Dudley's experimental results prove conclusively that at constant temperature a definite distribution of silver between lead and slag will occur, the silver passing either from the slag to the lead or from the lead to the slag as may be necessary to establish equilibrium. It is also shown that as the silver concentration in the lead increases, its concentration in the slag required to produce equilibrium will increase in direct ratio. That is, the ratio of the equilibrium concentrations of silver in metallic lead and in a slag of given composition is a constant at constant temperature. But the temperature has an enormous effect—an increase of temperature produces quite an increase in the solubility of silver in the slag.

In the second part of his paper, published elsewhere in this issue, Professor Dudley in discussing the effect of litharge shows that at constant temperature the ability of slags to dissolve and retain silver is mainly dependent upon the molecular concentration of the litharge and is independent of the so-called silicate degree or oxygen ratio of the slag. The slags may be regarded as simple solutions of the various oxides, and litharge is the only one having any appreciable dissolving power for silver.

The results are important in cupellation just as in assaying if we interpret the results as applying to pure litharge, and while the author states that much more experimental work is necessary before the physical chemistry of cupellation can be thoroughly understood, it is pointed out that further experiments should be made with pure litharge. The principal difficulty is in securing a proper container. Another field for further study is in regard to the condition or state in which silver is held in solution by litharge. The attack of the foregoing problems from the standpoint of physical chemistry has been very productive, and when further extended, the results should have an important bearing on the control of assaying and cupellation.

Readers' Views and Comments

Chemistry and the Daily Papers

To the Editor of Metallurgical & Chemical Engineering

SIR:—There seems no escape from Dr. Hesse's conclusion that the first point of entry for technical publicity must be by way of the editors of our dailies. But Dr. Hesse will probably have his work cut out to "educate our editors as to what the country should know." The unfortunate experiences which Dr. Hesse describes indicate this clearly; though this is not precisely the conclusion he draws from them nor does the real significance of the crowding-out of the results of his collaboration with "an efficient editorial writer" because the space was needed for something else seem to occur to him.

It is tremendously difficult to put a technical story into popular form in a way which will make it attractive and acceptable to the average person—and the average editor. *Hinc illæ lachrymæ.* It is not going to be done to any large extent by the newspaper man, if for no other reason than his lack of knowledge of the subjects to be dealt with. Perhaps it is also not going to be done to any large extent by the technical man since it is rare to find a technical man who can write attractively, still rarer to find one who can write for the standpoint of a layman, and he usually has enough to keep him otherwise busy. But it can be done, and if the chemist wants publicity he has got to do it. Unless he does it is of little use to complain of the consignment of his contributions to the waste-paper basket or of their being crowded out on account of lack of space.

F. AUSTIN LIDBURY.

Niagara Falls, N. Y.

Liquid Jets for Absorbing Gases in Liquids and the Flotation Process

To the Editor of Metallurgical & Chemical Engineering

SIR:—I have read with great interest in your issue of March 1 last an article designated "Universal Flotation Theory," by C. Terry Durell and beg that you will publish the following notes:

Mr. Durell is not the first man by any means to use the liquid jet as a means of absorbing either air or other gases into water.

In the year 1908 I erected an electrolytic chlorine generating plant for the Mount Morgan Gold Mining Co. of Queensland and by means of an acid-proof ejector using water under pressure instead of steam, I successfully absorbed 300 lb. of chlorine gas per twenty-four hours in 24,000 gal. of water. The chlorine water was used for leaching gold ores.

This ejector, which I could place in my pocket, replaced a 50 ft. tower and worked without interruption night and day for twelve months. Several years ago I tried to get the ejector tried in a flotation plant on two different mines at Broken Hill, being convinced that both its first installation cost as well as its running cost would be less than that of any other method. However, I could get no one to listen to me.

I am at present erecting a copper leaching plant for oxidized ores in which I intend to absorb sulphur dioxide gas into my solutions by means of ejectors.

In a recent paper entitled "The Electrolysis of Copper Sulphate Liquors Using Carbon Anodes," read by Mr. Lawrence Addicks before the American Electrochemical Society the author points out that it is impossible to obtain complete absorption in solution, of sul-

phur dioxide gas, derived from roaster fumes unless it be put under pressure. He has used a 50-ft. vertical pipe full of solution for this purpose, the gas being delivered at the bottom of the pipe by means of an air compressor.

An ejector, properly used, will absorb all the gas which it can pull with a given stream of solution, as the gas is subjected to pressure while passing through it and is forced into intimate contact with the jet.

If a small centrifugal pump and an ejector be placed in a closed circuit the circulating solution may very quickly be supersaturated with any gas.

I hope that Mr. Durell may have every success with his patent in America, but would warn him that his idea is not patentable in this country, as I placed it in commercial operation here about eight years ago.

B. DU FAUR.

Burra Copper Mine, Koorlinga,
South Australia.

Flotation and Cyanidation

To the Editor of Metallurgical & Chemical Engineering

SIR:—In your issue of May 15 you propose the following questions:

1. Are oil-flotation products—concentrates and tailings—as readily cyanided as similar products from ordinary wet concentration?
2. To what are the difficulties, if any, to be ascribed, and what are the remedies?
3. Are the difficulties likely to prove serious enough to react against cyanidation and restrict its use?
4. Is it possible that a combination of flotation plus smelting may in some cases prove more economical than cyanidation?
5. Does flotation appear to-day in any sense a competitor of cyanidation in the treatment of gold and silver ores, or will it prove a valuable accessory process?

The answers to questions 1, 2 and 3 can now be little more than suggestive, since the few plants practicing flotation upon gold and silver ores have not up to the present time, so far as I am aware, attempted cyanidation of any of their products upon a mill scale, and furthermore, published accounts of comprehensive scientific investigations covering these points have not appeared. The few results of empirical experiments so far published, as might be expected, have been contradictory, and therefore no definite generalizations can be made upon the basis of them. Most operators are in a hurry to derive the benefits from flotation at as early a date as possible, therefore—*rightly*—they have confined experimentation to empirical tests which would prove or disprove the suitability of their ores to flotation, and which would establish the factors for their particular cases which would result in the best economic result.

It appears that the tailing from flotation is, in the majority of cases, amenable to cyanidation; that is, provided that the original ore contained nothing to interfere. Regarding the cyanidation of the concentrate, there is a great variety of opinion. One well known metallurgist has published the results of tests made upon a flotation concentrate from a gold ore which leaves little to be desired as regards cyanidation, while another equally well known metallurgist has published results of tests which indicate that the flotation concentrate from another gold ore is not amenable to cyanidation.

This leads to the conclusion that the difficulty does

not always exist. In cases where it does exist, it may be due to the difference in the character of the ores treated, or to the difference in the behavior of the oil or oils used. The interference may be due to either physical or chemical causes such, for example, as a film of oil coating the mineral, or actual combination of certain constituents of the mineral with the oils used. This latter suggests itself on account of the well known fact that certain oils attack some of the metals. However, this is purely speculative since it has in no particular case been definitely proven.

The remedies suggested have been saponification of the supposed oil film by preliminary treatment with a caustic alkali, washing with a light mineral oil, such as gasoline, which is presumed to act as a solvent for the oil film, and various other expedients which have been tried more or less at random. The efficacy of these remedies in cases where real difficulty exists has not been clearly demonstrated. Where fuel is cheap and roasting can be done economically, a thorough oxidizing roast will with but very few exceptions solve the problem in the case of concentrate containing gold with little or no silver; but as I have elsewhere pointed out on a number of occasions, silver minerals are rendered refractory to cyanidation by an oxidizing roast. A chloridizing roast in such cases may be at times effective, but is not generally looked upon with favor by metallurgists, on account of the possibility of loss of the precious metals. The fear sometimes expressed that the oil may be carbonized during roasting and thereby cause premature precipitation is not well founded since with proper roasting it would be entirely consumed.

In my opinion, the difficulties even in the case of silver concentrate are not always insurmountable, but nevertheless there are doubtless cases where cyanidation could not be used.

There is no question but that a combination of flotation plus smelting will in some cases prove more economical than cyanidation. Here much depends upon the smelting rates and cost of transportation. A good example of a case where this works out advantageously is the practice at Cripple Creek, where flotation plants with shipment of concentrate are being introduced rather than expansion of existent cyanide plants. In fact, certain of the cyanide plants are being remodeled into flotation plants. It might be added that Cripple Creek is not by any means the only district where flotation is proving more economical than cyanidation, for a number of such cases have been brought to my attention.

It seems to be the opinion among thoughtful metallurgists who have not been completely carried away by the wave of enthusiasm which has swept the world for flotation that flotation will not to any considerable extent displace the cyanide process in the treatment of gold and silver ores, but as previously pointed out, it will in certain cases, perhaps a good many, prove more economical and it will in many other cases prove a valuable accessory treatment to cyanidation. The reason that flotation will not displace the cyanide process is that most companies prefer to produce bullion. Furthermore, many gold and silver mines are located far from smelting centers, which means high freight rates and renders the shipment of concentrate out of the question.

There is, however, one possibility which tends to render such a prediction uncertain, and that is the possibility of obtaining an extremely high-grade concentrate such as could be directly melted with simple furnace equipment in much the same manner as cyanide precipitate. If we can conceive of this ever being accom-

plished, and it is not impossible, then cyanidation will certainly have a most formidable rival in flotation.

G. HOWELL CLEVINGER.

Palo Alto, California.

Flotation and Cyanidation

To the Editor of Metallurgical & Chemical Engineering

SIR:—In the effort to extract gold and silver, by cyanide, from the concentrate obtained in flotation, experience is bringing out varied results. Much is being said in despair of operating the two processes conjointly. The usual flotation process depends upon the presence of oil in a mixture containing the ore which is agitated to produce the concentration. The cyanide process, in turn, is operative only by means of freely circulating aqueous solutions, which produce chemical reactions that are among the most intricate and delicate in all chemistry. For the proper action of these solutions, it is necessary that the dissolved cyanide enter into every minute passage of every porous grain to diffuse and to do its chemical work upon the metal. The oil of flotation thus becomes a harmful impediment in cyanide extraction. The flotation, which is desired to precede the cyanide extraction, furnishes a concentrate which practically consists of particles that have been oiled, or are oily. Though the extent of this oiling is in some measure adaptable to altered needs, and though the amount of the oil is, in all cases, extremely small, yet the effect is pronounced.

Were it not for the proverbial irreconcilableness of the oil and the water, the treatment of ore by a combined process of flotation and cyanidation would promise great economy. Cyanide treatment, in many cases would be a direct process for recovering the valued metal of the concentrate, without the costs involved in shipment and in smelting. A low extraction by the cyanide, however, is the usual result.

The interference to the extraction of gold or silver from the flotation concentrate is a result of physical action of the oil, and in addition to this, usually, also to certain chemical reactions by which cyanide is destroyed and the extraction retarded or prevented. There are, of course, many different kinds and qualities of flotation concentrate. The varied minerals and the variety of oils give rise to as many qualities of concentrate as there are places of operation. The substance which we regard as oil is not set apart by any determining chemical composition, nor definite nature. It ranges from liquid which is oily beyond all question to that which in reality is scarcely more than an alcohol, ether, or in some cases, an organic solution of a dissolved gum or resinous substance. Some of the so-called oils have little of the quality which we understand as characteristic of oil. Thus by including among the oils all those substances that have only some single semblance to oil, it is natural that the action of "oil" upon ores is varied. Among those oils which, by their numerous characteristic oily qualities, give no ground for uncertainty, there is varied susceptibility to saponifying and oxidizing agents and to solvents. Discrimination is the beginning of an effort to reconcile cyanidation with flotation.

The physical interference of certain oils in rendering cyanide solutions incapable of attacking the gold or silver of the grains of ore has been proven repeatedly by experiment and trial. The entire physical behavior of the concentrate is altered by the presence of the oil. The alteration was a necessity to produce the action that was sought for the flotation. While it is possible to obtain a flotation concentrate without the use of oil, this is commonly not practicable. Oil can be saponified and thus dissolved or washed away from any material in the form of a soap, or, when present in appreciable

amount, it can be removed nearly completely by simple oil solvents. Certain oils, moreover, are capable of oxidation and elimination through varied chemical reactions. Long treatment and agitation, without removing the oil, can be made to partly counteract the resistance offered by the oil. In the laboratory many such possibilities destroying or removing the oil seem indicated.

In the commercial treatment of ores, on the other hand, these delicate and erratic actions become sources of possible irregularities and are liable to influence from impurities. Roasting a concentrate is, of course, always a means of destroying or expelling an oil, but in some cases roasting is a hindrance to cyanidation and in all cases the operation seriously adds to the cost of treatment.

The greater number of oils allowed to remain in the flotation concentrate are not chemically without action upon cyanide solutions. Most oils have chemical qualities which also interfere by the absorption of oxygen. The animal and vegetable oils are generally oxygen-consuming. Combining with the oxygen at a critical time and place, when gold starts to combine with the cyanide and when the oxygen is needed, the extraction fails. Reduction and side reactions result in an attack upon the cyanide solvent. Particular interference is liable in the presence of the sulphide minerals soluble in alkali. Compounds, as well, between mineral bases and oily acids, produce physical effects that retard the dissolving action.

On the whole it is seen that ores must be judged for the application of definite oils, and that the oils must be chosen not alone for the merits which they show in flotation, but for the influences upon the cyanide extraction.

The mineral oils, for the most part, are among the most inert of all organic substances. These oils suffer little or no alteration through any treatment, and their harmful effect upon cyanidation is physical. The drying oils have found little favor in flotation. Between these two extremes in oils, with the quality of inertness on the one hand and readiness to oxidize, saponify or react, on the other, there are all gradations including oils of vegetable origin and extending through those produced by destructive distillation to those which are the natural petroleum products. Numerous oils are capable of offering both the physical and the chemical interference, and would always be avoided. Others introduce but a single interfering influence for which there would possibly be found a corrective.

Before flotation combined with cyanidation can be pronounced to be a general possibility with chosen oil, investigation must be made more extensive than even yet has been done. Study must be made of the properties of the many kinds of oils which are capable of employment in flotation. Many of these are imperfectly understood.

The effect which the oil has upon the surface tension of the liquid, its affinity for the different minerals, and the flocculating or thickening effect upon a froth or concentrate demands consideration along with the oxygen-consuming power, saponification in the alkaline solution, and the action upon the cyanide solvent.

In the choice of an oil the important requirements of flotation must be made subordinate to the demands of the cyanide treatment. There appears to be nothing permanently fatal, with further understanding, to a combination of the two processes of flotation and cyanidation, but there will be required a modification of present practice and a more discriminating understanding of the materials used.

ERNEST A. HERSAM.

Berkeley, Cal.

The Iron and Steel Market

The steel market has grown still more dull, and market conditions in the next two or three months are likely to approximate the summer conditions of a dull rather than of an active year. The condition is that of the market having been sold and bought to a standstill in the past few months, with prices now so high that new enterprise is discouraged. Railroad buying has practically ceased, and there is no business being done in fabricated steel representing regular investment, though there is a fair tonnage representing works extensions. Manufacturing consumers generally are well covered with material and in the retrospect it is more plainly evident that their importuning mills for better deliveries, as they have been doing for months, represented a psychological rather than a physical condition, a fear that they would not secure adequate deliveries in future rather than a condition of their actually needing more steel at the moment. In very few instances, it would appear, have manufacturing consumers received less steel than they really needed.

Exports

Iron and steel exports in April amounted to 385,000 gross tons, against 438,058 tons in March, April being the record month for exports, barring March and last August. Exports in the first four months of this year were at the rate of 4,600,000 tons per annum. The value of all iron and steel exports made a new record in April, at \$58,722,411, this value including that of machinery, hardware, cutlery, etc., as well as of the commodities reported by weight. The total value for four months of the calendar year is \$222,821,901. Besides these exports returned as iron and steel there is iron and steel involved in exports of agricultural implements, motor cars, railway cars, loaded shells, etc. Unloaded shells and locomotives are included as iron and steel.

Export demand has been particularly heavy the past two or three weeks, and there is large inquiry now pending. The shell steel for the balance of the year appears to have been practically all bought, sales since May 1 easily totaling more than half a million tons, while there remains large inquiry for bar wire for war purposes, Russian inquiries alone being estimated at more than 100,000 tons. What is perhaps more significant is that there is much heavy demand for steel products from neutral countries. To date our exports to neutral countries have been light, much smaller than in 1912 and 1913, hitherto the best export years.

Pig Iron and Steel

A rate of pig iron production of 40,000,000 tons per annum was approached within 2 per cent last February, but the full rate has not yet been attained, and 40,000,000 tons may prove to be the asymptote, at least until summer is over. For three months or more a common market opinion has been that with few blast furnaces being built and many extensions being effected to steel making capacity the time would arrive when there would not be enough pig iron, and then, as pig iron had advanced only about 45 per cent while steel, finished and unfinished, had doubled in price, pig iron would "go up." It does not do so, however, but on the contrary has turned a trifle weak in the past fortnight. Southern iron actually declining, and this is significant since almost invariably Southern iron leads the general pig iron market in both advances and declines. The theory that the unusually wide gap between pig iron and steel was destined to be bridged may prove correct eventually by steel declining instead of pig iron advancing. The market is very dull in all districts, and more foundries than formerly are requesting that shipments

be held back. We quote: No. 2 foundry iron, delivered Philadelphia, \$20.25 to \$20.75; f.o.b. furnace, Buffalo, \$18.50 to \$19; delivered, Cleveland, \$19.30; f.o.b. furnace, Chicago, \$19; f.o.b. Birmingham, \$14.75 to \$15; f. o. b. valley furnaces, 95 cents higher delivered Pittsburgh; Bessemer, \$21; basic, \$18.25; foundry, \$18.50; malleable, \$18.25 to \$18.50; forge, \$18. Ferro-manganese has grown very dull and can be bought at \$250 for prompt shipment, against \$400 obtained a few weeks ago. The contract market is unchanged at \$175.

Steel

The soft steel market has become still easier. Recently enough offerings of odd lots developed for prompt shipment to move the market from \$45 down to about \$40 to \$42, though even \$40 was shaded. For a time the large mills held forward deliveries at the \$45 level, but it is now evident that round tonnages for forward delivery could be bought at \$40 to \$42, either billets or sheet bars. There is very little inquiry, and the market is rather flooded with prompt lots, chiefly second discards and rejected steel, made against war steel orders.

Finished Steel

Regular mill prices, for forward delivery, are unchanged. Bars and shapes are 2.50c. and plates 2.90c. Premiums for prompt shipment show a declining tendency. Galvanized sheets are down from 5c. to 4.75c. on account of the decline in spelter.

The Non-Ferrous Metal Market

Saturday, June 10.—The last two weeks have been very dull most of the metals. Copper has held firm despite this dullness, while tin declined gradually until the last two or three days when it showed signs of an upward turn. The same is true of spelter. Lead was lowered $\frac{1}{2}$ cent by the Trust and the market still continues dull.

Copper.—The enormous production and small exports, combined with the overbought domestic market have contributed to make a dull market. Offers seem to be plentiful, but prices are at about the same level of 28.50 for prompt electrolytic. The markets abroad have also been dull. Exports for May were 14,622 long tons. Prices for future delivery are but very little lower than spot prices. Electrolytic for July and August is 28.25 and for September and October is 28.00.

Tin.—Up until a few days ago the tin market has been reacting both here and abroad. About the 7th of the month the market became more firm and developed an upward tendency. Spot Straits tin dropped from 47.00 on May 29 to 44.25 on June 6. To-day it is quoted at 44.50. The home consumption is good and arrivals for May were 3912 tons.

Lead.—On June 5 the Trust lowered its price to 7.00 cents. Independents are cutting this price and offerings are to be had at 6.90 and under. The market has been dull.

Spelter.—As in the case of tin, spelter was weak up until about June 5, when consumers began to take more interest in the market and a slight advance from 13.30 to 13.55 was made. Since then the market has continued firm, with a fairly good demand. Prompt spelter is quoted at 13.55-13.80.

Other Metals.—Antimony continues dull and has dropped to 22 cents, a decline of about 4 cents in the last two weeks. Aluminium is still quoted at 60 cents and platinum at \$78 per ounce. Quicksilver continues to drop and is now at \$70 per flask. Silver is quoted at 66½.

Concerning the recent slump in tungsten we comment on our editorial pages. As is shown there, it was an inevitable event.

New Revenue Measure Likely to Include Dyestuffs Tariff

The House of Representatives Ways and Means Committee is framing a new national revenue measure which is expected to include increased duties on dyestuffs, following closely the recommendations of the Hill bill. (An account of hearings on the Hill bill was given in our issue of Feb. 1, 1916, p. 125.)

In addition to providing for increased duties it is expected that provision will be made to limit the time, which the duties will remain in effect, and also that anti-dumping legislation will be included in the interests of fair trade. The committee has been considering the bill, which is concerned with general sources of revenue such as the income, inheritance and other taxes, for about two weeks and it should be reported out of the committee in a short time. Every effort is being made by the Democratic members of the committee to frame the bill so that it will meet with as little opposition as possible, and hopes are entertained that it may be passed by both Houses by July 1, or soon thereafter. The uncertainty connected with legislation must, however, be given due consideration.

Annual Meeting of Iron and Steel Institute in London

The annual spring meeting of the Iron and Steel Institute was held in London, May 4 and 5, at the Institution of Civil Engineers. The retiring president, Mr. Arthur Cooper, occupied the chair at the opening. An abstract of the annual report was read by the secretary, Mr. G. C. Lloyd. The number of new members elected fell considerably below preceding years, while financial statement compared favorably with other years. The new president, Sir William Beardmore, was inducted into office. He has been treasurer since 1912, and is chairman and managing director of William Beardmore & Co., Ltd.

The new president upon taking the chair presented the Bessemer Gold Medal to F. W. Harbord.

The new president in his address on science in factories emphasized the necessity of looking upon science as the dominant factor in industrial and economic considerations. There must be co-operation between laboratory research and manufacturing development. He also laid great stress on the attitude of workers, and said that their failure to utilize to the best advantage improved methods of manufacture evolved by experimental research discourages industrialists in their evolution and application. When a charge of lack of enterprise is made against manufacturers, blame should at the same time be laid at the door of the workers, who do not realize that their interests are intimately affected by the attitude they display in such cases. He thinks that research should be a charge on the selling price, and that it is essential that the volume of output should be increased. He is also in favor of a high rate of wage and large total earnings per worker per week. This is attainable without forfeiture of a satisfactory profit, provided all workers make the most of all the appliances which scientific research and mechanical experiment may place in their hands.

The awakening of the workers is as important as the furthering of scientific methods. Thus while we foster metallurgical science we must not neglect the equally important subject of industrial economics and the duty of the state and the worker towards such problems.

At the second day's meeting a discussion took place as to the position of the Institute in regard to trade

prospects after the war. The grants under the Carnegie Research Scholarship Fund were announced by the secretary.

Meeting of New York Section of American Chemical Society

The last meeting of the season of the New York Section of the American Chemical Society was held in Rumford Hall, Chemists' Club, Friday evening, June 9. The chairman, Dr. T. B. Wagner, presided, and the meeting was well attended. Upon recommendation of the committee, a resolution was adopted approving two bills introduced in the Legislature. These are the Johnson bill, to require the use of the Centigrade scale in all Government publications after 1920, and the Newlands bill, to establish industrial research stations in each State. (Two very interesting articles on the Newlands bill by Dr. W. R. Whitney were given in our issues of May 15 and June 1). Dr. George F. Kunz gave a short talk advocating the "more daylight" plan of moving the clock ahead as initiated by Germany and adopted by other countries.

The committee report on "University and Industry," presenting its findings, conclusions and recommendation, was read by Dr. Charles Baskerville, chairman of the committee. The committee advocates the appointment of a permanent committee, representing both universities and industries, such committee to study opportunities and make recommendations for co-operation.

A paper was presented by Dr. George A. Burrell of the Bureau of Mines, Pittsburgh, Pa., on vapor pressures and gas analysis by liquefaction and fractional distillation, and the extraction of gasoline from so-called "dry" natural gas by absorption methods. The paper was illustrated by numerous lantern slides, showing the apparatus used and results obtained in determining the vapor pressure of twelve gases at temperatures as low as -170°C . Experiments were also described on the deviation of gases from Boyles law at higher pressure, and it was explained that as the natural gases were more compressible at higher pressures than would be calculated from Boyles law, measurements of natural gas would have to be revised. Accurate gas analysis was developed by the liquefaction and fractional distillation method. Dr. Burrell explained recent developments in the extraction of gasoline from natural gas by absorption, a full account of which was given in our issue of June 1, page 651.

A paper was presented by Dr. Frederick E. Wright of the Geophysical Laboratory, Washington D. C., on the use of the petrographic microscope in analysis. The petrographic microscope is a valuable adjunct in chemical analysis, and Dr. Wright explained several important uses to which it has been put in the identification of solid materials. It is especially helpful in identifying mixtures of several different solids, the chemical analysis of which would require a long time. With the microscope the work can be done very quickly. Some interesting experiments were shown on the screen by a microscopic projection lantern. A few organic salts were melted, placed in front of the lens and then allowed to crystallize. The growth of the crystals could be seen very plainly, and the different characteristics of the different substances were apparent. These crystals appeared in colors as interference screens were used.

The Maryland Silicite Co., 609 Munsey Building, Baltimore, Md., is opening up a deposit of infusorial earth on the Patuxump River, Md.

Estimated Cost of Making Gasoline by the Rittman Process

The Bureau of Mines has issued the following estimates showing the cost of making gasoline by the Rittman process. These estimates are based on a five-tube plant and the results of a five-day run, with a recovery of gasoline of 17 per cent and with varying prices of fuel oil. (Fuel oil is oil from which gasoline has already been extracted by the ordinary process of refining.)

The capacity of a single tube was 1.55 bbls. per hour or 37.2 bbls. for 24 hr. With loss, 10 per cent, would yield 17 per cent gasoline, the balance being fuel oil, as valuable as original fuel oil.

The estimated cost of a five-tube plant.....	\$15,000.00
Estimated cost of building to house plant.....	5,000.00
Total	\$20,000.00

Monthly capacity, 5580 bbls. Deducting about 10 per cent for "shut downs" leaves net capacity 5000 bbls. Yield of gasoline 17 per cent, 850 bbls., or 35,700 gals. Loss, 10 per cent, equals 550 bbls. Residuum, 73 per cent, equals 3650 bbls.

COST OF FUEL OIL \$0.50 PER BBL.	
Expense.	
5000 bbl. fuel oil at \$0.50 per bbl.....	\$2,500.00
Labor for one month.....	560.00
Fuel (1050 M ft. at 15c.).....	160.00
Electricity	100.00
Repairs	100.00
Interest and depreciation, 6 per cent each.....	200.00
Refining cost 20c. per bbl.....	1,000.00
Total cost	\$4,620.00
Credit.	
3650 bbl. residuum at 50c. (fuel oil).....	1,825.00
Net Cost.	
Net cost of 850 bbl. (35,700 gal.) gasoline.....	\$2,795.00
Cost of gasoline per gal. 7.8c.	

COST OF FUEL OIL \$1.00 PER BBL.	
Expense.	
5000 bbl. oil at \$1.00.....	\$5,000.00
Labor	560.00
Fuel	160.00
Electricity	100.00
Repairs	100.00
Interest and depreciation, 6 per cent each.....	200.00
Refining cost	1,000.00
Total cost	\$7,120.00
Credit.	
3650 bbl. residuum at \$1.00 (fuel oil).....	3,650.00
Net Cost.	
Net cost of 850 bbl. (35,700 gal.) gasoline.....	\$3,470.00
Cost of gasoline per gal. 9.74c.	

COST OF FUEL OIL \$1.47 PER BBL.	
Expense.	
5000 bbl. oil at \$1.47.....	\$7,350.00
Labor	560.00
Fuel	160.00
Electricity	100.00
Repairs	100.00
Interest and depreciation, 6 per cent each.....	200.00
Refining cost	1,000.00
Total cost	\$9,470.00
Credit.	
3650 bbl. residuum at \$1.47 (fuel oil).....	5,365.00
Net cost.	
Net cost of 850 bbl. (35,700 gal.) gasoline.....	\$4,105.00
Cost of gasoline per gal. 11.5c.	

COST OF FUEL OIL \$2.10 PER BBL.	
Expense.	
5000 bbl. oil at \$2.10.....	\$10,500.00
Labor	560.00
Fuel	160.00
Electricity	100.00
Repairs	100.00
Interest and depreciation, 6 per cent each.....	200.00
Refining cost	1,000.00
Total cost	\$12,620.00
Credit.	
3650 bbl. residuum at \$2.10 (fuel oil).....	7,665.00
Net Cost.	
Net cost of 850 bbl. (35,700 gal.) gasoline.....	\$4,955.00
Cost of gasoline per gal. 13.9c.	

The Dolomite Products Company of Cleveland, Ohio, is erecting at Maple Grove, Ohio, a 450 x 85 ft. building for the manufacture of magnesite. The plant will be thoroughly modern and the processes entirely automatic. The plans have been worked out by the Schaeffer Engineering and Equipment Company of Tiffin, Ohio.

Faraday Society Meeting

The seventy-ninth ordinary meeting of the Faraday Society was held in London on May 9, 1916, with Sir Robert Hadfield, president, in the chair.

Theory of Gels

Mr. Emil Hatschek presented a paper on "an analysis of the theory of gels as systems of two liquid phases."

The generally accepted theory of the constitution of gels is that they are systems of two liquid phases. No attempts have been made to determine whether this assumption accounts for various observed properties of gels. The present paper is a mathematical investigation directed to determining whether the observed elastic properties of gels are compatible with their being composed of two liquid phases only. If this is the case, it follows that their elasticity must be due exclusively to the interfacial tension between the phases, viz., the work done in stretching a cylinder of gel must be equal to the surface energy developed. It follows immediately that the function connecting stress and elongation must be the first differential of that connecting surface and elongation. To obtain the latter, various structures, consisting of space-filling polyhedra such as rhombohedra, rhombic dodecahedra and cubes are examined and the increase in surface calculated for deformation in the direction of principal axes. The curves obtained by plotting surface as ordinates against elongation as abscissæ are similar in all cases and obviously represent the same function, although analytical treatment is only carried out for one case. Since the curves all show an inflexion, it follows that the stress reaches a maximum at the elongation at which the inflexion occurs and then decreases, i.e., to stretch the gel beyond this point a smaller stress would be required than for a smaller elongation. This, as well as the shape of stress-elongation curves obtained experimentally, which differ very considerably from the theoretical curve, shows that the assumption of two liquid phases is inconsistent at any rate with the elastic behavior of gels.

Prof. Alfred W. Porter, F.R.S., pointed out that Mr. Hatschek's criticism did not distinguish between an ordinary liquid and one as viscous, say, as cobbler's wax, which acted as a solid to forces applied rapidly. He thought, too, that in the case of two liquid phases the straight-sided forms assumed would not persist in equilibrium; the continuous would shrink away from the disperse phase and form gaps, unless the former were exceedingly viscous. Mr. Hatschek's argument was sound if polyhedra were formed.

Dr. C. H. Desch thought the geometrical forms of the structure would be neither rhombohedron nor rhombic dodecahedron, but Kelvin's fourteen-sided polyhedron with curved faces.

Mr. Hatschek, in his reply, added that he conceived gels as of an ultimate crystalline structure, with the crystals thinned and filled with liquid.

Solid Solutions of Metals and Intermetallic Compounds

In introducing two papers by Mr. F. C. Thompson, the president expressed his appreciation of the encouragement the University of Sheffield gave to young metallurgists like Mr. Thompson in the prosecution of research, and he remarked on the value of the author's work. As an incentive to him he offered a prize of £50 to continue his researches and present the results to the Faraday Society.

The first of Mr. Thompson's papers dealt with "the properties of solid solutions of metals and of intermetallic compounds."

By considering the space lattice of a solid solution of two metals as resulting from the substitution of atoms

of B for an equal number of A in the space lattice of the latter, it is possible to predict with some completeness the properties, hardness, specific volume, electrical resistance of the alloy.

The distortion of the space lattice resulting from this substitution of other atoms of different atomic volume explains the generally marked resemblance of the properties of solid solutions of metals to those of a metal which has been mechanically deformed. An elementary mathematical treatment results in a parabolic curve, which corresponds with that practically observed, for the relationship of hardness to concentration in a series of alloys, such as those of gold and silver which form an uninterrupted series of solid solutions.

The influence of the atomic volume on the readiness with which solid solutions are formed, and the properties of intermetallic compounds are also briefly considered.

Dr. C. H. Desch suggested that an examination of solid solutions such as that of gold and silver by means of Bragg's X-ray spectrometer might throw light on the structure of the space lattice.

Mr. Sydney W. Smith remarked that Roberts-Austen had long ago realized the importance of the gold-silver alloys as a means of attacking these problems.

Annealing of Metals

Mr. F. C. Thompson's second paper dealt with the annealing of metals.

After briefly considering the structural changes induced in metals and simple alloys by such processes as rolling or wire drawing, as a result of which the crystalline elements remain unchanged in hardness, the conditions governing such mechanical treatment of metals are examined.

The efficient commercial annealing of brasses, nickel-silvers, cupro-nickel, etc., is shown to differ radically from that necessary in the case of steel, the lowering to a minimum of the elastic limit being essential to allow a maximum further reduction at the next rolling before a further annealing is required, and also to minimize the loss of energy wasted in the production of merely elastic deformation.

The course of annealing of hard-worked copper, brass, and nickel-silver, taken as typical examples, is followed in some detail, and the influence of the temperature and duration of annealing, and of impurities in the metal dwelt upon. A summary of Charpy's classical work on the annealing of hard-worked brass, and of similar work by the author on the nickel-silvers is given.

Grain Size Measurements in Metals

A paper sent in by Mr. Zay Jeffries of Cleveland, Ohio, on "grain size measurements in metals, and importance of such information," was communicated by the president.

The author emphasizes the value to the user of physical tests of metals. Now physical and mechanical properties of metals vary greatly with changes in structure, and in the cases of pure metals and solid solutions the quantitative estimation of the structure can best be made by determining the grain size. Such measurements, however, only become important when correlated with the physical properties of the metal or alloy. The fact that these measurements do not break down the structure of the metal gives them a distinct advantage over mechanical tests in determining, for example, tensile strength or elastic limits, which are dependent on fineness of grain. The method is one of the best available for the determination of the relative quantities of crystalline and amorphous phases, and it is of special value in indicating the life of metals under vibration, in the estimation of the strength properties of alpha

brass, in indicating hardness, and in all probability in throwing light on certain corrosion problems.

The following methods for measuring grain size are briefly described: (1) the planimeter method, (2) the Heyn method, (3) the intercept method, (4) the method of comparison with known samples, (5) the author's method. This method, for which great rapidity as well as accuracy is claimed, consists in counting the grains completely included and partly included in the circular portion of an image of the specimen of standard magnification, and by means of an empirical formula determining therefrom the equivalent number of whole grains in the standard area. The apparatus and manipulation required for the measurements are described in some detail and a few simple rules for sampling are laid down. In the interpretation of results care must be taken to distinguish between grain-size and cell-size. In cold-worked metals that have been annealed and sometimes in cast metals the grains will often be elongated, but in elongation due to cold-working measurements parallel and perpendicular to the direction of working show fairly constant ratios.

The president, in commenting on the paper, referred to the enormous tenacity attained by metals at extremely low temperatures, due probably to the closeness of grain. It was unfortunate that a limit was soon reached, for instance, in hardened steel, below which the grain was too fine for Mr. Jeffries' method to be applied. He hoped further research would overcome this difficulty; perhaps some method like Bragg's might be applied. He mentioned that whereas a 0.58 per cent carbon steel contained 5540 grains per square inch as forged, and 4500 as forged and annealed, the number rose to 330,000 when the steel was water-quenched and reheated.

Dr. C. H. Desch agreed with the author that the intercept method was not reliable.

Mr. F. C. Thompson, in the course of remarks on the relation of physical properties of iron and steel to grain size, said in these cases another factor had to be considered, namely, the fineness of the carbide in the grains, as well as the size of the grains themselves. He preferred as a unit number of grains per unit length to number per unit surface. Shock tests gave a better measure of crystalline size than tensile tests.

Mr. S. W. Smith suggested that the rate of corrosion might in some cases be used as a measure of grain size.

Specific Heats of Hard and Soft Aluminium

A paper by Dr. F. J. Brislee, on "the changes in physical properties of aluminium with mechanical work [II. specific heats of hard and soft aluminium]," was read by Dr. R. Seligman, in the absence of the author.

A series of determinations of the specific heat of hard-worked aluminium and annealed aluminium was made. The metal was used in the form of rod and wire. It was found that the specific heat of the hard aluminium was higher than for annealed, and this confirmed the view that aluminium is converted into an amorphous form by excessive mechanical work. It was further found that the specific heat underwent a change when the hard-drawn bars and wire were heated to 100 deg. C. A sample of wire was prepared by drawing with the maximum draft possible, whereby a high tensile strength was obtained, but the wire could not be bent without fracture. The worked metal had a tensile strength of 18.4 tons per square inch, and after heating to 100 deg. C. for ten weeks the tensile strength was reduced to 13.2 tons per square inch, but whereas the original metal was brittle and could not be used, the metal with the lower tensile strength was quite serviceable.

It is therefore necessary that the determinations of

all the physical constants of metals shall be made upon metals in a perfectly definite state and one which can be reproduced. If this is not done, the results are fortuitous and may differ quite widely from the true results.

Further investigation is being made to obtain aluminium wholly in the amorphous state.

Dr. R. Seligman, while agreeing with the author's conclusions, was unable to see how he arrived at them from figures given in the paper. He criticised the author's use of different temperature ranges for the various sets of experiments. Dr. Brislee's observation of the change of the specific heat of hard-worked aluminium under the influence of so low a temperature as 100 deg. C. might possibly be of great technical importance. He did not agree that as a general rule aluminium after ten hours' heating at 500 deg. C. was, although "dead-soft," still largely amorphous in structure.

Dr. J. A. Harker thought it a mistake only to take ordinary temperatures as the norm in studying the relation between composition and physical properties of metals and alloys. If the melting point were taken as the starting point in, say, a series of specific heat measurements, the matter of the previous thermal history of the specimen would not be a disturbing factor. There would be no great difficulty in devising a suitable calorimeter for such measurements.

Annealing of Aluminium

Dr. R. Seligman and Mr. Percy Williams presented a "Note on the annealing of aluminium."

The authors found that hard-worked aluminium which had been heated for ten hours at 125 deg. C. was less readily soluble in nitric acid than the same metal before heating, but that if the heating were continued for eighty hours, this comparative immunity from attack was lost.

They also found that metal which had been freshly annealed at 440 deg. C. was less readily attacked by nitric acid than the same metal which had been allowed to stand for ten days after annealing.

Dr. H. Borns asked what precautions had been taken to prevent oxidation before making the solubility tests.

Dr. R. Seligman said the samples were all immersed in caustic soda.

Theory of Solutions

Mr. E. J. Hartung presented a paper entitled "A contribution to the theory of solution."

The author has tested the divergence in physical properties from those calculated by the simple mixture law shown by two completely miscible liquids which do not visibly react with each other. This divergence has been ascribed by Denison to solvate formation. The liquids used for the experiments were aniline, methyl alcohol, carbon tetrachloride, ethyl ether and chloroform. Measurements were made of the density, heat capacity and heat change in mixing of mixtures of selected pairs of these liquids.

The evidence adduced shows that, in the cases examined, no simple solvate theory will suffice to explain the experimental results, even though the liquids used, with one exception, are little associated. Also, a study of the deviation curves obtained from many other liquid pairs by various authors leads to the conclusion that only in rare cases, if at all, will the conditions be simple enough to permit of an explanation of the deviations by single solvate formation. In the great majority of cases the molecular condition of a mixture of two liquids is much more complex, and it becomes very difficult to develop and apply any satisfactory quantitative theory to such a mixture.

An Electric Arc Furnace for Laboratory Use

BY OLIVER P. WATTS, PH.D.

Several years ago a simple, inexpensive and easily made electric furnace for crucibles was developed in the university laboratories by the writer, and used in the preparation of a large number of iron alloys.* Recently two small arc furnaces of 10 lb. capacity have been constructed for the melting of metals and the making of alloys. Since these are proving well adapted to such use, it is thought that a description of them may be of assistance to those desiring a small furnace for experimental work on a laboratory scale.

In view of the many electric steel furnaces of the arc type now in operation, and the numerous descriptions of these available, it would seem a simple matter to construct a satisfactory furnace for melting metals in the laboratory. This, however, is not so easy as it appears. The small size of the furnace, the short time allowed for melting, and the extremely refractory metals which the laboratory furnace may be called upon to melt, all complicate the problem. The laboratory furnace is far more severe on refractories than commercial furnaces because of the proximity of the sides and roof to the arc, and to the more sudden and frequent heating and cooling, due to its intermittent use. Although heat insulation may be no more important in the laboratory than in the works furnace, on account of its thinner walls, it is desirable to use some special heat insulator in the laboratory furnace instead of employing only the commercial refractory materials used in steel furnaces. The method in which these and other difficulties have been met will be seen in the description.

The nature of the work requires a tilting furnace, which means that the weight should be kept as small as possible. This restricts the furnace to the smallest dimensions which will contain a crucible or melting pot of the desired capacity, and a sufficient thickness of heat insulation. For greater ease of construction and lining with brick, a rectangular form was chosen instead of the more ideally perfect sphere or cylinder.

The furnace body is made of sheet steel $\frac{1}{8}$ in. in thickness and is $16\frac{1}{2}$ in. long, $14\frac{1}{2}$ in. wide, and $17\frac{1}{2}$ in. high in front and back, and $11\frac{1}{2}$ in. high on the ends. After the electrodes and lining were in place the ends were raised to the height of the front and back by thrusting pieces of galvanized sheet steel down inside the end walls. If another furnace were to be designed the walls would all be made of the same height with slots in the ends to accommodate the electrodes.

Refractories

Due to the severe usage to which it must be subjected, magnesia was the only material considered for the melting pot, which was constructed of magnesia brick $2\frac{1}{4}$ in. thick. The corners were filled with a cement of electrically fused magnesia moistened with a solution of sodium silicate, so that there might be no places for metal to lodge when the furnace is tilted for pouring. The melting pot is $8\frac{3}{4}$ x 6 x 7 in., and has a capacity of 12 lb. of metal. By setting the electrodes higher its capacity could be increased to 18 or 20 lb. if desired.

Although magnesia brick are so refractory that they give no trouble from melting, as a roof for a small arc furnace they last only a few heats. They usually crack across the middle the first heat; with further use other cracks form, pieces drop out, and the roof soon fails. A new departure was therefore tried for the roof. A lump of electrically fused magnesia was prepared in a 60-kw. arc furnace. This was sawed in two by the

Grant Marble Company of Milwaukee, producing two slabs of a beautiful crystalline structure, $11 \times 8 \times 2\frac{1}{4}$ in., weighing about 20 lb. each. One of these slabs was used for the roof of each of the two furnaces already constructed. One of the furnaces has been operated seven afternoons with no apparent injury to the roof, although one day a temperature of 2190°C . was measured inside the furnace with the power off. Graphite is the only other material ever used by the writer which could have withstood such service, and graphite was impossible for the roof of this furnace, from the standpoint of oxidation, of electrical conductivity, and of contamination of the charge.

Heat Insulation

The high thermal conductivity of magnesia brick and fused magnesia when hot made it necessary to provide special heat insulation. Infusorial earth, usually considered the best insulator, could not be employed because the temperature would occasionally be far above the melting point of silica. Magnesia is an important ingredient of the insulation commonly used on steam pipes, but it cannot be used here. Effective insulation depends on porosity—on a multitude of air cells in the insulating material—and magnesia frits to a solid mass at temperatures occasionally attained by the melting pot of these furnaces. The insulating material must not only retain its porosity at extremely high temperatures, but it must not flux with magnesia at, or even above, 2000°C . Previous experience had shown that air-slaked lime fulfills these severe requirements to a remarkable degree, and this was therefore chosen for the insulator. Since enough of this could not be obtained promptly, an exceptionally pure lime was slaked to dryness by the minimum amount of hot water.

Two inches of slaked lime was tamped into the furnace, and the melting pot previously described was built upon this. The space between the pot and the steel shell, 2 in. at the ends and 3 in. at front and back, was also filled with slaked lime. In order to pour the metal it was necessary to build a bridge of magnesia from the melting pot to the spout, and to cover this the roof of fused magnesia extended forward within $\frac{1}{4}$ in. of the shell of the furnace, making two breaks in the heat insulation. The roof was covered to a depth of 2 in. with slaked lime, and a sheet of asbestos and a wire screen were placed over the top to hold the lime in place when the furnace is tilted.

Fig. 1 shows the furnace before the roof was put on.



FIG. 1—ELECTRIC FURNACE BEFORE ROOF IS PUT ON

*Electrochemical & Metallurgical Ind. 4, 273 (1906).

and Fig. 2 is the completed furnace, except that the steel shell was cut away over the spout to a height of 3 in., so that the spout can be used as a charging door. This is closed by a magnesia brick when the furnace is in operation. The total weight of the furnace is 334 lb., yet it is readily tilted for pouring by one man. Exclusive of refractories the cost was \$50 each. The linings were put in by students as class exercises.

Electrode Holders

The electrode holder is shown in Fig. 3. This consists of a casting of red brass, bored for a $1\frac{1}{2}$ -in. electrode. The top of the holder is split, and can be clamped to the electrode by means of two stout screws. Water-cooling is essential, and was provided for by drilling holes in the holder and inserting small copper tubes to which pieces of $\frac{1}{4}$ -in. rubber tubing are attached. One of these connects the holders with each other; to the others standard hose couplings are permanently fastened for convenience in attaching the $\frac{1}{2}$ -in. hose by means of which water is carried to and from the furnace. The electrodes are moved by a screw feed actuated through pinions by a crank beneath the electrode. Since it would often be desirable in melting metals to



FIG. 2—COMPLETED ELECTRIC FURNACE

operate without a slag, the usual vertical arrangement of the electrodes in steel furnaces was not desirable, and the electrodes were inclined so that they meet at an angle of 90 deg. above the furnace charge. This arrangement has proved satisfactory, although through carelessness students sometimes feed one electrode too far into the furnace, so that the arc plays upon the side instead of the tip of the electrode, and they may even push an electrode into the metal. This technical defect has an educational value, for it is not well that students should work with foolproof apparatus. On account of their position, there is a tendency for the holes in the roof through which the electrodes pass to act as chimneys, and cause a draught of air through the furnace; this results in undue oxidation of the electrodes unless a packing of asbestos or similar material is placed around the electrodes where they pass through the roof. To prevent the loose lime on the roof from falling into the furnace when an electrode is removed, tubes of magnesia, extending from the roof to the top of the layer of lime, were built around the electrodes.

Electrodes

On account of the space occupied the diameter of the electrodes was fixed at $1\frac{1}{2}$ in., as the largest size that could well be used. It was expected that at 20 to 25 kw. carbon electrodes could be used without their heating to the temperature of oxidation outside of the furnace, while on the few occasions when more power must be used graphite electrodes could be substituted.

The advantages of carbon electrodes are:

1. Lower cost.
2. They are obtainable in 3-ft. lengths, instead of the maximum of 2 ft. for graphite, thus greatly lessening stub-end waste.
3. Their poorer thermal conductivity results in much less heat loss than with graphite electrodes of the same diameter.

By maintaining the voltage above 75 it has been found possible to use 20 kw. without serious oxidation of carbon electrodes. This is sufficient power for most purposes. For 25 to 30 kw. graphite electrodes are employed.

Although the electrodes have been referred to as passing through the roof, they really emerge from the end walls of the furnace. There are no holes in the slab

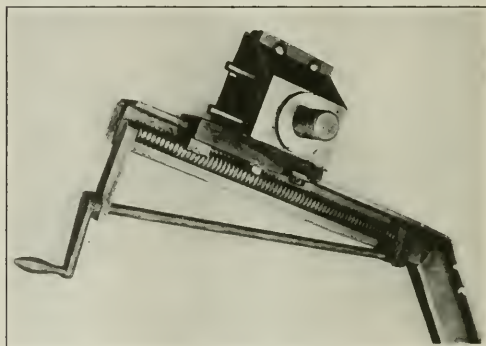


FIG. 3—ELECTRODE HOLDER

of fused magnesia, which just fills the space between the electrodes. The end walls are built up around the electrodes to the level of the roof with the cement of fused magnesia and sodium silicate solution previously referred to.

Operation

In melting metals it is desirable to heat the furnace before putting in the charge, in order to shorten the time that the metal is subjected to possible contamination by carbon from the electrodes or by oxidation. It is advisable to use a mold that can be lifted to the spout of the furnace, thus avoiding the loss of material and likelihood of freezing, incident to the use of a ladle with such small quantities of metal.

An alloy of nickel, chromium and tungsten, contain-

Time	Kw.	TABLE		Interval
		Volts		
2.15	30	70		
0.25	30	70		
0.40	20	81		
0.45	25	Charged 10 lb. of iron.		30 min.
3.00	22.5	80		
0.09		Poured and recharged 10 lb.		24 min.
0.15		22.5		
0.20		78		
0.27		Poured and charged 10 lb.		12 min.
0.31		Restarted.		
0.35		25		
0.50		Poured and charged 10 lb.		19 min.
0.54		70		
4.05	20	68		
0.07		Poured and charged 10 lb.		13 min.
0.10	20	64		
0.22		Poured.		12 min.

ing 40 per cent of the last metal, was cast directly into a mold without difficulty.

The log of a furnace run on cast iron is given in Table I.

Power was on the furnace for an hour and thirty-six minutes, and 35 kw.-hr. were required to melt and pour six heats, totaling 50 lb. of metal. The time required for the successive melts is shown at the right.

At another time when using 30 kw. 11½ lb. of cast iron was melted and poured in six minutes after the furnace was well heated.

To test the effectiveness of the heat insulation mercury thermometers were placed against the back and one end opposite the melting pot, and covered with steam-pipe insulation. The furnace was then heated, and at intervals the current was interrupted and the temperature within the furnace was measured through a hole made in the door made for this purpose by means of a Holborn-Kurlbaum optical pyrometer. The log of the run is given in Table II.

TABLE II
LOG OF TEST

Time	Kw.	Volts	Temperature		
			Back	End	Inside
2.30	26	90			
0.35	30	80			
0.40	35	45			
0.45	30	88			
0.55	37	64			
3.09	37	64			
3.08	0	0			
0.15	37	64	48 C.	40 C.	1920 C.
0.25	0	0			
0.30	37	64	77	61	2130
0.40	0	0			
0.42	20	80	106	88	2190
0.47	0	0			
4.02	0	0	142	102	
0.10	0	0	180	114	1600
0.19	0	0	194	124	1500
0.25	10	102	219	142	1395
0.30	30	90	235	157	
0.45	28	90	251	178	
0.52	0	0	256	183	1990
0.53	28	90			
5.05	0	0	272	196	1990
0.06	24	92			
0.20	0	0	292	214	2150
0.28	0	0	313	228	1760

Interruption of the current is indicated by zero values for kilowatts and volts; the time of restarting is shown by the next significant figures in these columns.

Although the lime insulation did not melt under this severe test, it shrunk considerably over the center of the roof, and a red hot spot at that point required the addition of more lime during the test. Most of the heat loss indicated by the rapid cooling when the current was cut off at 3.47 occurred around the spout. The heat conductivity of fused magnesia proved so great that the steel shell was entirely melted away in front of the roof; a small piece of the spout was also melted. The only serious damage was caused by the melting of a portion of a very refractory alumina brick used as a door during a part of the test. This ran down inside the furnace and fluxed the bottom. For operating at this high temperature better insulation of the front of the furnace is required, and can be secured by lessening the thickness of the magnesia which extends through the insulation to the shell, and by covering the outside of the magnesia door by a heat insulator.

Laboratory of Applied Electrochemistry,
University of Wisconsin

Instruments for Recording Carbon Dioxide in Flue Gases.—The Bureau of Mines has undertaken the testing of several different types of apparatus for the analysis of flue gases and published the results in Bulletin 91. Awakened activity in power-plant economies has brought many new forms of carbon dioxide apparatus on the market. The tests were made under service and laboratory conditions and the results show the factors which may affect the accuracy of a CO₂ recorder and the manner in which a recorder should be tested.

The Sherardizing Process

BY OLIVER W. STOREY

The present conflict in Europe has caused a spectacular rise in the price of most metals. Zinc has been one of those affected, the present price being about 13 cents compared with 6 cents under normal conditions. Zinc dust, or the so-called "blue-dust," necessary for the sherardizing process, has jumped from 7 to 40 cents with little available. Users of the sherardizing process are necessarily interested, with the present high price of zinc dust, in securing a maximum of protection with a minimum expenditure of zinc. It is the purpose of this article to show how this may be best accomplished, together with an explanation of the fundamental principles involved.

It has been within the past decade that the sherardizing or "dry galvanizing" process has taken its place among the many methods used to protect iron and steel against corrosion. The method of applying the zinc is different from either the electro or hot galvanizing processes. It is applied by heating the objects to be coated in finely divided zinc to a temperature well below the melting point of zinc. When the process is properly carried out the resulting coating is hard and crystalline and consists of an iron-zinc alloy high in zinc which protects the iron base.

The finely divided zinc used for the sherardizing process is usually the so-called "blue dust" obtained as a by-product from the zinc smelter. This "blue dust" is a zinc dust of extreme fineness, each metallic zinc particle being covered with a film of oxide. A prepared "sherardizing zinc" is also on the market consisting of practically pure zinc powdered to about 100 mesh fineness. This is often used in connection with "blue dust" but is probably never used alone. A granular zinc-iron alloy¹ of the composition FeZn₂₀ is used to a limited extent.

The sherardizing process is the invention of Sherard Cowper-Coles, an Englishman. While the first patents were granted about fifteen years ago, it was not until 1908 that the first commercial plant was in operation in the United States. Since then the process has come into extensive use for certain classes of articles.

The articles that are most successfully treated are nuts, bolts, screws, nails, pipe fittings and the like, small castings and various intricate shapes which cannot be perfectly coated by the older processes. Sherardizing is especially adapted to small articles that can be loaded into drums and afterward separated from the dust by screening. Pipes are also being successfully coated both on the interior and exterior. Large flat pieces such as sheets are treated with difficulty. Up to the present time continuous sherardizing of wire and similar products has not been entirely successful.

The principles involved in the sherardizing process were not entirely unknown previous to the time of Cowper-Coles' patent, for in 1838 Miles Berry took out a British patent in which he coated iron and copper in a manner similar to the present process. Various other patents of a similar nature were granted from time to time, but none of commercial importance. The ancients hardened copper in a manner similar to the present cementation process for carbonizing iron and resembling the methods employed in sherardizing. In certain localities they placed the copper in the ground which was heated for a period of time by building fires over the place. Needless to say the ground in these favored localities contained zinc or tin ores. Brass was made, up to the beginning of the last century, by heating cop-

¹Burgess, C. F., Coating Iron by Applying Granular FeZn₂₀ and Heating. U. S. Patent No. 1,014,749.

per in contact with zinc ores, a process similar to sherardizing.

At the present time the process is carried out in the following manner. The articles, previously cleaned of all dirt, scale, or grease, are imbedded in a drum of suitable zinc dust and are heated for the proper length of time to the correct temperature, removed from the furnace and allowed to cool. The zinc dust is then separated from the coated articles by screening. As the metallic content of the zinc dust drops, it is maintained at the proper percentage by the periodic addition of new dust. Theoretically this is a comparatively simple process.

Unfortunately when sherardizing was first introduced into this country many extravagant claims were made for the process as is so often done with new inventions. As the process came into use there were many disappointments because these extravagant claims were not borne out in practice and as a result the commercial development was slow until the nature of the process was understood and its limitations ascertained. The statement that "the sherardizing process adds nothing to the surface of the article" caused the greatest amount of trouble. The claim was made that "you can take a screw from your watch—sherardize it, and you can replace it again without rethreading." Where screw-threads were sherardized on this assumption, the indignation and wrath of the manufacturer may be imagined when threads came back for recutting. As zinc is added to the surface of the iron due allowance must be made for it.

While the sherardizing process has been in commercial use for almost a decade, it is doubtful whether the average quality of sherardizing has been improved during that period except in a few instances where a thorough study of the process has been made. In making tests of the work turned out by various manufacturers, the writer has found that the quality varies greatly. In some cases, the protection afforded, even with a heavy deposit, was small while in other instances thin coatings were practically indestructible under ordinary weathering conditions.

The difference in quality of the different deposits is caused by a difference in the methods used for the deposition of the zinc. A lack of understanding of the effect of the relation of time, temperature and metallic content of the dust on the quality of coating formed has resulted in the deposition of poor coatings. To fully understand the relation of the above variables to the quality of the coating it is necessary to know the nature of zinc-iron alloys.

Alloys of Iron and Zinc

The exact compositions of the alloys of zinc and iron are not known. The solubility relations of the two metals have been studied by Wologdine² and von Vegesack³ but the results of these two workers are not entirely in agreement.

Both investigators show that iron is totally insoluble in zinc in the solid state. The freezing point of the zinc increases rapidly with increase of iron. The first freezing occurs at 419 deg. for the pure zinc which rises to 755 deg. at about 8 per cent of iron. Both diagrams show that pure zinc separates out from the alloy up to about 7 per cent of iron.

The diagrams beyond 8 per cent of iron are not in agreement. Wologdine shows that at this point the freezing temperature reaches a maximum after which the curve drops again. Unfortunately he did not work with alloys containing more than 10 per cent of iron.

With more than 9 per cent of iron a secondary freezing took place at 685 deg. This would seem to indicate that an eutectic occurs at between 10 and 11 per cent of iron. The maximum point on the curve at about 8 per cent would seem to indicate that a chemical compound is formed which would have the composition FeZn_{10} , and which Wologdine succeeded in isolating. This compound appears to dissolve a small amount of zinc though the data are incomplete on this point. At above 8 per cent of iron it seems to form an eutectic with one of the compounds richer in iron.

Von Vegesack's diagram, on the other hand, shows no discontinuity at 8 per cent, the freezing point increasing steadily with an increase in iron content. At 10.9 per cent, he shows that the compound FeZn_{10} is formed which corresponds closely with Wologdine's eutectic at 685 deg. The compound FeZn_{10} is shown to dissolve between 3 and 4 per cent of zinc in the cold so that the point of maximum solubility of these two constituents is between 7 and 8 per cent of iron corresponding to the FeZn_{10} of Wologdine's diagram. Von Vegesack also shows that the compound FeZn_{10} is formed.

If iron is added to a bath of pure zinc at a temperature slightly above the melting point of the latter it will dissolve readily. If about 4 per cent is dissolved, which gives the alloy the consistency of ordinary galvanizer's dross, and is examined under the microscope, the alloy will be found to consist of a number of brilliant, hard, definite crystals imbedded in a matrix of pure zinc. With 4 per cent of iron these crystals cover about one-half the field. If these crystals, which are much less soluble in acids than the pure zinc matrix, are analyzed, they will be found to contain about 8 per cent of iron. As the percentage of iron in the alloy is increased and the amount approaches 8 per cent the entire alloy consists of these crystals. On the other hand as low as 0.07 per cent of iron in zinc can be detected under the microscope by these crystals.

This 8 per cent alloy is peculiar in its properties. If it is melted and allowed to cool in a crucible, the freezing proceeds normally. When it cools to a low red heat after freezing, recrystallization takes place and the alloy, if not under pressure, will expand and break the crucible. If the alloy is allowed to cool in a spelter mold it will rise very much like a loaf of bread. If the metal is of the correct composition, it then will crumble and consist of a mass of loose crystals.

These crystals may also be made by tumbling the requisite amount of iron with zinc kept at just above the melting point of the latter. A loose mass of brilliant crystals will result.

Whether the peculiar alloy formed at 8 per cent of iron is the compound FeZn_{10} or whether it is a solution of zinc in FeZn_{10} cannot be definitely settled until the solubility relations of the two metals have been rechecked.

By analogy it appears that the brittle alloy containing 8 per cent of iron should be a definite compound, FeZn_{10} , and not a solid solution of zinc in FeZn_{10} . It is known that solid solutions are perfectly homogeneous and malleable⁴ and all industrial alloys which are capable of being cold rolled, drawn, or spun, are solid solutions. Eutectics are more or less brittle and intermetallic compounds have the same property. The FeZn_{10} is of definite crystal form and extremely brittle and has none of the properties of a solid solution and all the properties of an intermetallic compound.

The meager and conflicting data on the solubility relations of zinc and iron make the exact nature of the al-

²Wologdine, S., The Alloys of Zinc and Iron. *Revue de Metallurgie*, Vol. 3, 1906, p. 539.

³Von Vegesack, A., *Zeit. anorg. chem.*, Vol. 52, 1907, p. 30.

⁴Law, E. F., The Failure of the Light Engineering Alloys, Particularly the Aluminum Alloys. *Trans. Faraday Soc.*, Vol. 6, 1911, p. 185.

loys formed in sherardizing of some doubt. Before the process can be fully explained these data will have to be obtained.

The swelling of the zinc-iron alloy is not peculiar to it alone, but has been noted in several other alloys, for example, in one of iron and aluminium.⁴

Iron Content of Sherardized Coatings

Several investigators have made a study of the zinc-iron alloys formed in the sherardizing process but the conclusions reached have differed. These investigators have found the iron content to vary from 9 to 30 per cent and the coating to consist of from 1 to 4 layers of different zinc-iron alloys. A result of these conflicting statements is that it is difficult to understand the exact nature of the coating formed in the sherardizing process.

These conflicting results obtained may be correlated when it is shown that the iron content of the sherardized coating is a function of the temperature used, which in turn is determined by the percentage of metallic zinc in the dust. If the investigators had given these data their results would have shown the alloys that were formed at different temperatures and concentrations of zinc.

The writer has determined to a limited extent the effect of temperature on the iron content of sherardized coatings. The analyses were made on coatings of approximately the same thickness. The time of deposition was the same while the concentration of zinc in the dust determined the temperature necessary to secure the necessary thickness of coating. Unfortunately it was impossible to secure accurate temperature measurements as the experimenting was done with large drums traveling through a tunnel type furnace.

The metallic content of the zinc dust varied from 18 to 42 per cent, the variation in temperature necessary for these extremes being about 65 deg. C., the higher metallic content requiring the lower temperature. With a metallic content of 18 per cent the iron content was 22.45 per cent while with a metallic content of 42 per cent the iron content of the coating dropped to 11 per cent. These percentages were obtained with a coating of about 0.6 ounce per square foot. The data obtained with intermediate metallic percentages showed that the iron content of the sherardized coating is proportional to the temperature used, the rate of deposition being constant. Tests were not carried out to determine the composition of the coating with a dust of varying metallic percentages at a constant temperature.

From the above data the variation in iron percentages reported by earlier investigators and the differences under the microscope are explained. The investigation of the sherardized coating with reference to its structure is incomplete without a knowledge of the depositing conditions.

The higher the temperature of deposition the higher the percentage of iron in the alloy provided the rate of deposition is the same. The increased quantity of the base metal alloyed with the zinc at the more elevated temperatures is easily shown when copper is sherardized. Here the colors are such that the resulting alloys are easily recognized.

When a piece of copper is sherardized at a comparatively low temperature, about 300 deg., the coating will consist of a hard silvery alloy with traces of an intermediate yellow alloy. This hard silvery coating of copper and zinc cannot be "touched" by a file and will take a high polish.

If the copper is sherardized at a comparatively high temperature, 400 deg., and then cooled slowly, the coating will be found to consist of two definite layers. The outer layer will consist of the hard, silvery, crystalline alloy previously mentioned while the intermediate layer

will consist of an alloy having the color of yellow brass. These two alloys, together with the copper base, form definite layers that do not merge into each other with a gradual gradation of color but are sharply defined as though formed by the piling up of sheets of vari-colored metal. No pure zinc was found at any time on the surface.

When etched and viewed under the microscope the junction of the three layers, copper, brass and white metal, reveals another peculiarity. The structure of the outer two layers is granular like that of pure annealed iron while that of the copper is less definite. The dividing line between the yellow and white brass does not follow the grain outlines but cuts across these grains. The granular structure of the two brasses is continuous.

An analysis of the two layers, these results being checked on several specimens made in different heats, showed that they were of definite composition. The outer silvery layer showed a composition of about 67.3 per cent zinc and 32.7 per cent copper which corresponds to the formula CuZn_{11} , while the inner or yellow brass layer corresponded to the formula CuZn or about 50.7 per cent zinc and 49.3 per cent copper. If the heating is prolonged enough, the entire specimen changes to CuZn_{11} .

By heating the copper and zinc dust to various temperatures and for different periods of time it was thought possible to form other layers than those mentioned but the above alloys always resulted.

From the above data it appears reasonable that copper and zinc form two definite intermetallic compounds at sherardizing temperatures, CuZn and CuZn_{11} , and that no others are formed. These data should be of help in interpreting equilibrium diagram data for the copper-zinc alloys.

The results obtained in sherardizing copper show that the higher temperature results in a higher copper content of the coating and that the alloys formed are in definite layers, each having a definite composition corresponding to an intermetallic compound.

Since iron and zinc and their alloys are of the same color it is difficult for the eye to detect distinct layers on sherardized iron. For this reason, the layers cannot be removed as readily and analyzed. But by proper polishing and etching methods, the sherardized iron structure may be studied.

Since the solubility data on iron-zinc alloys are conflicting it is impossible to know what compounds and solutions these metals form. Without these data it is impossible to assign a definite composition to the layers formed on sherardized iron. By analogy to the copper-zinc results it is reasonable to suppose that with low temperatures a high-zinc alloy will be formed while at high temperatures a high-iron alloy will be formed.

Burgess⁵ in his investigation of the sherardized coating shows but one main layer to be formed. This layer, by analysis, corresponds closely to the formula FeZn_{11} . Only a very thin film of relatively pure zinc is formed on the exterior while there is an indication of a thin alloy between the FeZn_{11} and the iron. This thin alloy is probably higher in iron. That the samples used by Burgess were made at a low temperature is indicated by the low iron content. The FeZn_{11} compound, when alloyed to the iron, has a peculiar fissured appearance. This appearance is due to the peculiar crystallizing effects previously noted when this alloy is cooled from the molten state. This compound is shown by Burgess to be present also in hot galvanized iron.

Arthur and Walker⁶ show that the main layer formed in sherardizing under certain conditions of time, tem-

⁵Burgess, C. P. Sherardizing Magazine, Vol. 1, March, 1910.

⁶Arthur, W., and Walker, W. H., Structure of Galvanized Iron. Jour. of Ind. Eng. Chem., Vol. 4, 1912, p. 397.

perature, and concentration of zinc dust, consists of the peculiar fissured alloy previously noted by Burgess. They also point out that a second thin alloy high in iron is formed between the main alloy and the iron base. They assign the formula FeZn_2 to this material. They also state that if the time of deposition is lengthened and a dust high in zinc is used a layer of pure zinc will form on the exterior of the sherardizing. Definite proof of the composition of the various alloy layers investigated is lacking, owing to the absence of reliable solubility data.

In their description of the structure of galvanized iron Arthur and Walker show that crystals of the iron-zinc alloy are present in the zinc. The formation of the alloys between the iron and zinc is also noted.

The structure of the sherardized iron depends entirely upon the time, temperature, and concentration of the zinc dust used. With the high temperature necessary with a lean zinc dust alloys high in iron will be formed on the surface. With a rich zinc dust and a low temperature the alloy formed will be high in zinc and may have some free zinc on the exterior though this layer of zinc will be thin. Johnson and Woolrich¹ state that it is impossible to sherardize pure zinc which would seem to indicate that it is impossible to obtain a coating of pure zinc of any appreciable thickness on the exterior of sherardized iron.

Theory of Sherardizing

Several theories have been advanced in trying to explain the formation of the coating in the sherardizing process. None have been entirely satisfactory.

Hinchley² advances the explanation that the magnetic oxide is first formed in the heating of the articles and that this oxide is subsequently reduced by the metallic zinc with the formation of zinc oxide and the zinc-iron alloy. But when it is shown that sherardizing can be carried out more easily in a vacuum where the magnetic oxide is not formed, this theory does not hold.

The vapor theory, which has been generally accepted as explaining the mode of zinc deposition, states that the zinc vapor present, due to the slight, though appreciable vapor pressure of less than 0.100 millimeter, is sufficient to allow enough zinc to be condensed on the iron to form the protective alloy. Although the vapor pressure of zinc at sherardizing temperatures is almost negligible that of the finely divided zinc or blue dust is several times greater. That this is the cause of the relatively higher rate of deposition than could be obtained from ordinary zinc is the basis of the vapor theory.

The vapor theory is not without objections. The writer has experienced much trouble in the sherardizing of large pieces of flat work in non-revolving boxes. If the dust was not in close contact with the entire area those parts which were not touched by the dust were not sherardized. Hinchley³ also states that if a cavity of 0.001 in. is left about the article to be sherardized only the points of contact are acted upon. In commercial sherardizing, zinc oxide in varying amounts is often found enclosed in the coating which would not be probable if it were purely a vapor process.

The sherardizing process should not become confused with the vapor coating process. The inventor of the sherardizing process also coats iron or steel by subjecting it to the vapors of zinc at a temperature which is much higher than that used in the sherardizing process. But with the low vapor pressure of zinc, at the sherardizing temperature, even in the form of dust, the

amount of condensation or other vapor alloying action must be small, and it does not seem reasonable to attribute the large amount of metal deposited to the vapor alone.

If strips of polished copper and zinc are clamped together so that considerable pressure is exerted between the two pieces, and these are then heated to about 350 deg. C. for about twenty minutes, the copper strip will become covered with a white alloy, CuZn_2 , showing that alloying has taken place.

If two similar strips, placed together but under no pressure, are heated in a non-oxidizing atmosphere, no alloying or welding action is observed and the copper is uncolored by the zinc except at the points of contact. Intimate contact obtained by pressure was required in the first instance to secure alloying action, while in the second, though the metals were in close proximity, no action took place. If a vapor formed no evidence of condensation is visible on the copper. Copper is used in these experiments because of the color formation which makes the alloying action easy to detect.

The metal zinc is chemically active when compared to the other common metals, such as tin, lead, copper, nickel and iron. This property is common to the three metals of the subdivision of the periodic group to which zinc belongs. Mercury and cadmium are the remaining members.

The chemical activity of mercury and the ease with which it forms alloys or amalgams with many metals is a universally known property. Zinc is next to mercury in its chemical activity while cadmium is the least active.

From our knowledge of the similar properties of the elements in a periodic group we would expect zinc and cadmium to have properties similar to mercury, but to be less active. This is found to be the case. While mercury amalgamates or alloys with many metals in the cold, there is but one metal, gold, with which zinc will amalgamate or alloy with in the cold.

If a thin film of gold is plated onto zinc and allowed to stand for a few weeks at atmospheric temperature the gold will have completely disappeared and become alloyed with the zinc. Other metals will alloy with zinc in a similar manner, but require a more elevated temperature.

In considering the sherardizing process and the alloying action of zinc and iron at relatively low temperatures, it becomes necessary to consider similar results obtained with other metals.

In 1896 Roberts-Austen⁴ showed that it was possible to alloy gold and lead at temperatures well below the melting point of lead, and even at temperatures below the boiling point of water. At higher temperatures the process is much more rapid so that gold is able to rise against gravity to a height of 7cm. in lead at 250 deg. in less than a month. The latter temperature is 77 deg. below the melting point of lead.

Gold⁵ diffuses in silver at 800 deg., the diffusivity being of the same order as that of gold in lead at 200 deg.

Spring⁶ showed in 1894 that carefully surfaced cylinders of copper and zinc, heated six or eight hours at 400 deg., formed a layer of yellow alloy to a depth of 0.8 mm.

In considering the theory of the deposition of zinc in the sherardizing process some experiments taken from a thesis on "sherardizing" submitted by the author at the University of Wisconsin in 1910 will be of interest.

¹Johnson, A. R., and Woolrich, W. R. Zinc Cementizing, Trans. Am. Electrochem. Soc., Vol. 21, 1912, p. 561.

²Hinchley, J. W. Some Practical Experience with the Sherardizing Process. Trans. Faraday Soc., Vol. 6, 1911, p. 133.

³Roberts-Austen, Phil. Trans. Vol. 187A, 1896, p. 383.

⁴Desch, C. H. Metallography, 1910, p. 217.

⁵Spring, W. Bul. Acad. roy. Belg., Vol. 28, 1894 (III), p. 23.

Antimony was found to behave in a manner similar to zinc, and iron could be easily coated by antimony at the low temperatures used with zinc dust. The antimony used was the ordinary commercial material which had been granulated in a mortar. The antimony also coated copper easily, and formed two layers, one of which was identified as the purple SbCu_2 . Zinc specimens were coated by the antimony while antimony could be sherardized in zinc dust. The coatings on the zinc and copper specimens formed by the antimony were loose and adhered but slightly to the base.

Aluminum could not be sherardized with zinc or antimony at the temperatures used.

Aluminum dust did not coat iron or zinc, but copper was affected and turned a golden color. (Iron may be coated by aluminum by a process similar to sherardizing in the so-called calorizing process, though the temperature is above the melting point of aluminum.)¹²

Copper powder used as a sherardizing material did not coat, probably due to the formation of the oxide.

Arsenic coated both the zinc and copper heavily and easily, while iron was not affected by it except at higher temperatures than those used for sherardizing.

In view of the above data showing that sherardizing may be carried out with various metals, especially antimony, at temperatures used ordinarily in sherardizing with zinc dust, and where the vapor tension is practically nil, it does not appear that the action in the case of zinc should be entirely different. If the action of antimony or aluminum is by contact why should not the action of zinc be that of contact? While the vapor may play a small part in the case of zinc, especially when the temperature approaches the melting point, it is probably mostly contact action. This action will probably occur most readily where inter-metallic compounds are formed, and for this reason the sherardizing may be a measure of the affinity of certain metals, and may be of use in determining the constitution of alloys.

Desch¹³ states that: "Microscopical examination shows that union takes place particularly between those metals which form inter-metallic compounds, but that the typical eutectic and other structures characteristic of solidified metals are not produced. The fact of union is most patent when metals which form colored compounds, such as copper and zinc, or copper and antimony, are heated together."

The data show that the formation of alloys below the melting point depends almost entirely on the formation of inter-metallic compounds. A few exceptions are noted where solid solutions are formed as in the case of gold and silver. Our information on the composition of alloys is too meager to formulate any definite law. This phase of the study of the formation of alloys has barely been touched upon and offers a rich field for further research.

Diffusion also plays an important part in sherardizing and in the formation of alloys below the melting point of the constituent metals. After the first alloying at the surface of the metals takes place solid diffusion commences. The two metals diffuse through the alloy formed from a place of higher to lower concentration until equilibrium is attained.

Zinc has the property of forming compounds with many of the metals and this activity is probably the basis of the sherardizing action. Without the ability to form compounds it is doubtful whether the reactions involved in sherardizing would occur below the melting point of zinc. This is illustrated by the action of powdered zinc on copper.

Copper and zinc form a series of solid solutions when

melted together. Yet when copper is sherardized under varying conditions two compounds are invariably formed, CuZn and CuZn_2 . No other proportions of the two metals have been found.

One of the principles involved in chemical reactions is that a more finely divided material is more active than one less finely divided since a more intimate contact between the reacting materials is obtained. The finely divided zinc dust is in such shape that it is in more intimate contact with the article to be sherardized than ordinary granulated zinc would be and this is borne out in sherardizing practice. The ordinary "blue dust" adheres so well to any surface that it can only be removed with difficulty. Many chemical reactions cannot be carried out successfully unless the materials are finely divided and in intimate contact.

Johnson and Woolrich¹⁴ show that when the articles are not tumbled finely divided zinc dust is not as rapid in its action as a coarser dust. But the opposite seems to be true from practical experience when the container is revolved. If the container remains stationary they show that with zinc dust of 100 to 150 mesh fineness it is deposited nearly twice as rapidly at 370 deg. C. in three hours than with the finest zinc dust. The coating obtained with the coarser material was much rougher as is often found in commercial practice. It is also stated that the coarse zinc dust particles had a tendency to fuse together at that temperature.

The above statement shows that the zinc at the sherardizing temperature is more or less plastic and can be easily welded or joined to other metals in the same manner that iron, platinum and other metals may be welded together well below their fusing temperature. By the vapor theory the coating should not be rough but this work shows that the zinc particles actually become welded to the iron or the alloy and in that way quickly form a rough and heavy coating. This welding action is aided by the formation of the inter-metallic compounds.

When an article is tumbled with coarse zinc, the inter-metallic welding action cannot be carried to completion due to abrasion in contrast to the opposite condition when no tumbling occurs. This explains the high rate of deposition for coarse particles obtained by Johnson and Woolrich in comparison to the finer zinc dust. In commercial practice the finer particles react more quickly and are welded and alloyed completely with the iron before they can be removed by abrasion.

The necessity of intimate contact is again shown by Weyl's¹⁵ experiments in which he carbonized iron with pure carbon by contact at temperatures above 1000 deg. C. in a vacuum. Here the reaction between iron and carbon to form iron carbide did not take place until intimate contact between the iron and carbon was secured. No gases were necessary to carry out the carburization.

In the same way, a low-carbon and high-carbon steel may be heated in contact with each other¹⁶ and no transfer of carbon from the high to the low carbon steel will result unless the surfaces were previously polished and pressed firmly together. These surfaces ultimately weld together.

The various instances given show that metals unite below their melting points under proper conditions and by analogy the active zinc will unite with iron, copper, nickel, and other metals below its melting point because of the affinity of the metals involved as shown by the inter-metallic compounds formed.

Johnson and Woolrich,¹⁷ in support of the vapor theory,

¹²Ruder, W. E. Calorizing Metals. Trans. Am. Electrochem. Soc. Vol. 27, 1915, p. 253.

¹³Desch, C. H. Metallography, 1910, p. 219.

¹⁴Weyl, Fritz. Cementation in a Vacuum by Means of Pure Carbon. Metallurgie, Vol. 7, p. 440.

¹⁵Adams, F. W. The Diffusion of Carbon in Iron. Engineering, Vol. 100, 1915, p. 95.

carried out experiments in which they sherardized iron with various alloys of zinc that contained small percentages of other metals. Those mentioned were zinc-aluminum, zinc-tin, and zinc-iron (FeZn_{10}). The rate of deposition of coats on iron or copper from these alloys was less in every case than for pure zinc. They also found that if copper was sherardized with FeZn_{10} the white alloy formed below the melting point of zinc contained no iron while with increasing temperatures above this the percentage of iron increased. These data are not entirely in accord with results obtained by other investigators. Where the diluting metal does not form an inter-metallic compound with iron or zinc it probably will not be found in the resulting coating. While the data presented are not in conflict with the vapor theory they also are in accord with the contact theory.

The presence of a second metal will dilute the zinc so that the action will not be as rapid if the metals used do not form compounds directly with the iron. The character of the diluent, whether it is sand or a metal, is not of moment, provided it is not as active toward iron as zinc.

While engaged in commercial work in sherardizing the writer had occasion to make some 15 to 20 tons of FeZn_{10} for sherardizing purposes. It was found that by the addition of from $\frac{1}{2}$ to 1 per cent of aluminium the oxidation was cut down appreciably and the coating was much whiter. An analysis of the coating formed on iron showed aluminium to be present. This does not bear out the experiments of Johnson and Woolrich¹ who state that aluminium when present in the coating medium will not be found in the coating if the temperatures are kept below the melting point of zinc.

Hinchley² also states that if other metals, whose oxides are reduced by zinc, are present in the zinc dust, these metals will appear as impurities in the coating.

The writer found that if the white zinc-copper alloy, CuZn_{10} , containing 31.9 per cent copper, formed when copper is sherardized, is used for the coating of iron no action takes place even at a low red heat. On the other hand copper is readily coated by means of the iron-zinc alloy, FeZn_{10} , with the formation of CuZn_{10} . Here we have an irreversible reaction. The affinity of the copper and zinc is evidently much greater than that of the iron and zinc.

The action of FeZn_{10} in sherardizing is not fully known. The temperature required to sherardize with this material is slightly higher than with the zinc dust and the coating always contains a higher percentage of iron than the FeZn_{10} , the total iron being usually from 12 to 16 per cent. In commercial practice it has been found that the FeZn_{10} may be used for sherardizing purposes for a long period of time without any increase in its iron content. This would seem to indicate that the FeZn_{10} is deposited as such on the iron though it is not the case with copper.

With the data presented and by a consideration of the laws of physical chemistry as applied to the formation of alloys it appears to the writer that the sherardizing action is mainly a contact action when carried out at the usual temperatures. This contact action is made possible by the formation of inter-metallic compounds. Zinc vapor may enter into the action at low temperatures but it is only at the higher temperatures, that is, near the melting point of zinc, that the vapor tension becomes high enough to enter appreciably into the reaction.

Trood³ first explained the process as due to the porosity of the iron, the zinc vapors entering and depositing in these pores. He likened the process to the

absorption of hydrogen by palladium and of ammonia by charcoal. He⁴ later modified his first theory by stating that at the sherardizing temperature iron and zinc vapors are formed which produce ionic charges. Owing to the difference of potential of the ionic charges, ionic discharges occur which precipitate zinc with traces of iron. There is little evidence to support these two theories.

Effect of Iron in Coating on Its Weathering Properties

The iron in the sherardized coating has an important effect on its weathering properties. The writer has found that coatings containing high percentages of iron withstand weathering poorly.

While all of the zinc-iron alloys are electropositive to iron⁵ their ability to withstand corrosion varies. The zinc-iron alloys rich in zinc, when exposed to the atmosphere, will usually turn a deep gray and finally black. At other times the surface will turn a pale yellow or red due to the oxidation of the iron in the surface alloy or in the adhering dust. This coloration will gradually become darker and turn black. This black coating is supposed to be the magnetic oxide of iron. Sherardizing which has this surface formation, becomes highly resistant to further corrosion. But this magnetic oxide is not formed in all cases.

The writer, in testing coatings containing varying percentages of iron, has usually found that those containing high percentages, above 15 to 20 per cent, are not as resistant to corrosion as those containing lower percentages. The sherardizing soon became covered with red iron oxide. Instead of turning black this oxide did not change in color and became flaky and penetrated to the iron in a short period. Such sherardizing practically afforded no protection.

The amount of iron in the zinc dust used also is important. If the zinc dust used is high in iron, 2 to 4 per cent, the dust clinging to the coating will turn red when it becomes moist. A heavy layer of iron oxide is formed immediately and this appears to penetrate to the iron base more easily. A few tenths of 1 per cent of iron in the dust will discolor the product. By keeping the zinc dust free from iron, the surface of the sherardizing cannot become colored until the iron in the coating is attacked. The coloration obtained in that manner turns to the black oxide more readily.

When the coating is high in iron the structure is more or less complex as it consists of several alloys. The potential of these alloys decreases with the increase in iron content and as a consequence the electrochemical action between the various layers results in a more rapid destruction of the coating. For this reason the sherardizing should be done so that the coating will consist of a single layer of alloy or a condition approximating that. And that result can probably only be obtained at low temperatures.

The writer has found that some manufacturers were unable to turn out as good a coating at the end of a year as when they first installed the process. When the process was new the metallic content of the zinc dust was high while the iron content was negligible. As a result a low temperature was used and a good coating was obtained. As the zinc dust was used the metallic content dropped and the iron content of the dust increased due to various causes. The temperature required for sherardizing had to be increased and as a result the coating became less resistant to weathering.

The most satisfactory results are obtained with coatings that will turn directly from the silver gray sherardizing to the deep gray and finally black magnetic ox-

¹Trood, Samuel. Theory and Practice of Sherardizing. Iron Age, July 23, 1914.

²Trood, Samuel. Sherardizing. Am. Inst. of Metals, Sept., 1915.
³Vigoroux, E., Ducléliez, F., and Bourbon, A. Bull. Soc. Chem. Vol. II, 1912, p.480-5.

ide. While a yellow or red coloration is not harmful if it eventually turns to the black magnetic oxide, the color gives the article sherardized a rusty and poor appearance which is detrimental to its further sale. To avoid trouble, the yellow or red oxide should not be formed.

Results Obtained at the General Electric Company¹⁹

To obtain the best possible results in service corrosion tests, the sherardizing process has been studied in detail at the General Electric Company. By studying the process in detail the practice was standardized and a coating was obtained that gave satisfactory results under highly corrosive conditions.

It was found that in order to secure complete control of the process it was necessary to have complete temperature control and an unvarying quality of zinc dust. Electric heating was found to give the best results.

The zinc dust used consists principally of the so-called "sherardizing-zinc," a granulated zinc, with an addition of a small proportion of "blue-dust" or oxide. It contains from 80 to 92 per cent of metallic zinc. It would be impossible to run "blue-dust" with this high metallic content due to its caking. With the electric heating there is also no danger of over-heating as is the case with the gas fired or other direct fired furnace. With such a high metallic content the temperature regulation has to be close. The temperature used is about 365 deg. C.

The zinc dust is run through a magnetic separator from time to time and in this way is freed from iron. This prevents an undesirable accumulation of iron in the dust which causes an early discoloration of the coated articles.

A study of their data on sherardizing shows that the specific gravity of the coat under a certain set of conditions varies from 1 at 35 per cent of metallic zinc in the dust to 6.75 at 80 per cent. This shows that the coatings obtained under the usual sherardizing conditions are more or less porous or contain occluded oxides, etc.

The specific gravity has a decided influence on the resistance of the coating to corrosion. By means of the salt spray test it was found that only a coating with a density of at least 6.75 would stand up satisfactorily. This means that if the sherardizing is done with a dust containing less than 80 per cent the salt water spray tests will be unsatisfactory due to the porosity of the coating.

Further Corrosion Data on Sherardizing

Burgess²⁰ carried out an extensive investigation on sherardizing which included corrosion tests.

The sherardized coating was shown to adhere firmly to the underlying iron. In the acid corrosion tests the iron-zinc alloy was less easily attacked and therefore equal weights of hot or cold galvanizing were not as resistant.

The sherardizing coating had an average single potential of about 0.20 volt which would make it positive enough to protect iron. Burgess states: "The potential of the alloy coating is in the neighborhood of 0.20 to 0.25 volt as against 0.50 volt for pure zinc. It fulfills therefore the requirements of being electropositive to iron and it is probable that the slower rate of corrosion as compared to the more electropositive forms of zinc, is due to the fact that it is not electropositive to a wasteful degree. In the potential measurement, therefore, we see a very definite reason why a sherardized coating is more resistant to galvanic action than are other forms of zinc."

Burgess found that the yellow appearance of the coating after exposure to the atmosphere was not harmful as it was merely the oxidation of iron in the dust clinging to the surface or the oxidation of the iron in the surface of the coating. This yellow color gradually became darker and finally turned black after which it was highly resistant to corrosion.

Leighon and Calderwood²¹ carried out a series of tests on electrogalvanized and sherardized conduits and reported favorably for sherardizing.

Sherardized, cold-galvanized, and hot-galvanized fence wire erected by the American Society for Testing Materials in Pittsburgh, Pa., at the Carnegie Technical Schools were inspected by the writer in June, 1915, just previous to their removal. These had been exposed for about 6 years to the weather.

The cold-galvanized fence wire was almost completely destroyed. The hot-galvanized, which had been heavily coated without wiping after fabrication, was in good condition, except for the top row of vertical strands. All of these were covered with heavy rust. Two sherardized fences were erected. One, with a light zinc coating, was in fair condition with corroded strands in several places. The second section of sherardized fence wire, heavily coated, was in perfect condition though almost black in color. By sharply bending the wire, the coating beneath the black coloration was shown to be intact.

Tests by various investigators have shown that when the sherardizing is carried out properly the resulting coating gives excellent service under atmospheric conditions. Whether it is preferable to electro or hot galvanizing depends upon the service to which it is to be put and the material to be coated.

While it is generally true that the protection afforded an article is measured by the thickness of the zinc coating this must be modified for certain conditions. It is known that a heavy sherardized coating is brittle and will flake when bent or hammered and for this reason a heavy coat cannot be applied under all conditions.

Sherardizing properly carried out by means of granular FeZn₉₀ free from fine dust, gives the same corrosion results as the coatings obtained with zinc dust. As the articles are freer from dust, the formation of the yellow oxide is less pronounced.

Commercial Sherardizing Practice

For a detailed description of the methods used in sherardizing plants the reader is referred to the articles mentioned in footnotes 8, 15, 17, 22, 23, 24.

Following is a discussion of several important details in commercial sherardizing practice based upon data obtained by the writer while actively engaged in sherardizing practice.

Removal of Zinc Dust from Coated Articles

The problem of removing zinc dust from sherardized articles is one of the most difficult to solve as it adheres tenaciously to most surfaces. This is especially true if the surface is slightly roughened as by over-pickling. Smooth surfaces, such as are obtained on cold-rolled steel, do not allow the zinc to cling and such material is easily cleaned.

Not only is adhering dust objectionable in the further handling of the work but it also results in a more rapid deterioration of the coating by corrosive agents, as has been previously pointed out. If the articles have to be tumbled in sawdust or other similar material to remove

¹⁹General Electric Co. General Facts About Sherardizing. Bulletin Y 694, 1915.

²⁰Burgess, C. F. Sherardizing Magazine, 1910.

²¹Leighon, R. B., and Calderwood, H. A. Report of Tests on Sherardized and Electro-Galvanized Conduits. Carnegie Institute of Technology Bulletin, 1912.

²²Liggett, T. About Sherardizing. Metal Industry, Vol. 11, p. 16.

²³Lucas, C. F. The Practical Side of Sherardizing. Machinery, Vol. 21, 1915, p. 361.

²⁴Storey, O. W. Sherardizing. Wisconsin Engineer, Vol. 16, 1912, p. 300.

the adhering zinc dust, this will usually discolor the coating. Dipping in paraffin is objectionable because of its greasy nature. Dipping in varnish is not applicable to many articles.

The problem of dust removal may be overcome to a large degree by using a high percentage of "sherardizing zinc" in the dust. It may be almost completely overcome by using granular FeZn_{10} from which the fine dust is removed by an air separator. By using this material not only can a brilliant crystalline coating be obtained but also one that is practically free from dust.

Sherardizing of Retorts

When the process was first used, the claim was made that the interior of the retorts were not sherardized. This has not been found to be correct, the writer finding that retorts in daily use were lined with a zinc-iron alloy 1/32 to 1/16 in. in thickness. After this was once formed it became hard and adhered tenaciously, and the retorts apparently did not suffer further deterioration from this cause.

Zinc Dust Control

While temperature control of the process is essential for the best results, the percentages of metallic zinc in the zinc-dust must be kept under control. The dust should be analyzed for metallic zinc at least once a week and preferably daily. The new "blue-dust" should also be analyzed for its metallic content. The iron content of both the new and old dust should also be determined.

For the analysis of new "blue dust" the writer prefers Drewsen's Method²². This method depends upon the reduction of an acidified potassium dichromate solution by the finely divided zinc in the presence of sulphuric acid. Other methods²³ are the hydrogen evolution method carried out in a nitrometer with decomposing flask, reduction of potassium iodate to iodide in the presence of caustic potash, and the reduction of ferric sulphate.

For the routine analysis of used zinc dust for metallic content the hydrogen evolution method is the simplest and easiest, and gives results that are accurate enough for factory control. The amount of hydrogen evolved by dilute sulphuric or hydrochloric acid from a weighed sample is compared under prevailing temperature and pressure conditions with C. P. granulated zinc. The percentage of metallic zinc in the dust is proportional to the hydrogen evolved from the C. P. zinc.

While the hydrogen is easily evolved from used zinc dust, new dust is dissolved with difficulty due to its physical nature. A simple hydrogen evolution apparatus cannot be used with new zinc dust but can be used for old dust.

Testing of Sherardizing

While the testing of the sherardized product is required under specifications, it also serves as a check on the zinc dust and temperature used. Test pieces should be put into every retort and tested by some standard method to determine the amount of coating deposited. Although the copper sulphate or Preece method is extensively used for testing purposes, many objections have been raised to its use and other methods have been proposed.

It is well known that the copper sulphate method gives varying results with different kinds of galvanizing and that such tests are not comparable. The pure zinc coating obtained with cold galvanizing will be attacked almost twice as fast as the sherardized coating. Hot-galvanized coatings will dissolve at another rate. The bul-

letin of the General Electric Company²⁴ shows that there is even a discrepancy when sherardized coatings of varying weights are tested.

But the Preece test has a certain value. For routine factory testing the writer knows of no better method for determining the weight of the zinc deposit. Here the results are comparable, especially, where the coating does not vary by more than two or three copper sulphate dips. The writer used this method for more than two years to test the output of a 40-ton sherardizing furnace and trouble was seldom experienced. No difficulty was encountered in determining the end point as the copper always plated out brightly when the iron was exposed and was dark and loosely adherent while the sherardizing was intact.

The results obtained by the Preece test were checked from time to time by the basic lead acetate method.²⁵ The latter method was used to accurately determine the weight of deposit per unit of area and also to remove the coating for analysis.

For a rapid analysis of the coating and if its weight per unit area was desired within a reasonable degree of accuracy (within 0.2 per cent) the writer devised the sulphuric acid method. This method was found to be of special value where a large number of deposits were to be investigated. The writer found that 2 per cent sulphuric acid would dissolve the coating readily without dissolving an appreciable amount of the iron base, the results being repeatedly checked by the basic lead acetate method. The loss of coating of the sherardized article was determined by weighing before and after removing the coating with 2 per cent sulphuric acid.

The specimen was removed from the acid when hydrogen practically had ceased coming off. The iron was immediately determined by titrating the solution with potassium dichromate. In this manner the weight of the coating and its percentage of iron were easily and rapidly obtained. This method would not be applicable where the iron base dissolved rapidly in cold 2 per cent sulphuric acid but with ordinary steels and irons the writer found that the iron dissolved was negligible if the specimen was removed when the zinc had dissolved.

The Preece test, basic lead acetate, sulphuric acid, and similar tests will give results which will show the thickness of deposit. While these tests do show the amount of coating they will not show the amount of protection to the iron base that the coating will give as determined by factors other than the thickness of the deposit.

Final judgment can only be given when the coatings are exposed to the atmosphere for a sufficient length of time to secure a breakdown. Even then the results obtained are for a certain set of conditions for it is obvious that different results will be obtained at the seashore, or in the coke regions of Pennsylvania than in dry climates where only a slightly corrosive atmosphere is found.

To secure results applicable to maximum corroding conditions, the General Electric Company²⁶ has developed the salt spray test. This test gives corrosion results in a week or two that would usually require several or more years of atmospheric exposure. This test is of much value but should be checked up from time to time by atmospheric tests.

Conclusions

1. The exact composition of the zinc-iron alloys formed in sherardizing cannot be known until the solubility relations of the two metals have been determined.
2. The coating consists of definite layers of iron-zinc compounds.

²²Lunge, G. Technical Methods of Chemical Analysis, Vol. 11, Part I, 1911, p. 299.

²³Sutton, F. Volumetric Analysis, 1903, p. 385.

²⁴Walker, W. H. Method of Testing Galvanized Iron to Replace the Preece Test. Jour. of Ind. & Eng. Chem., Vol. 3, 1911, p. 239.

3. The iron content of the sherardized coating is a function of the temperature.

4. Sherardizing is principally a contact action made possible by the formation of inter-metallic compounds.

5. Sherardizing, when carried out properly, gives a coating that is highly resistant to corrosion.

6. A zinc dust having a high metallic content will give the best coating.

7. Sherardizing should be carried out at the lowest temperature economically possible to secure a low iron content in the coating.

8. A high iron content in a sherardized coating is detrimental to its weathering properties.

9. The copper sulphate test gives excellent results for daily furnace control tests.

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Coke as a Reducing Agent in the Electric Smelting Furnace

BY R. C. GOSROW

The use of coke as the reducing agent in the electric smelting furnace, has been the subject of considerable argument, and some articles of literature, on the part of electrometallurgists. The experiences of several operators on this class of operations have been written up in the technical journals of the metallurgical art. Among the foremost to investigate and publish the action of coke in the electric smelting furnace in the manufacture of pig iron, were the Swedish and Norwegian metallurgists. From their experiences and data, more has been written, in the form of discussions, by American metallurgists. These data have been taken from one source and another without any verification of the statements transcribed. As a result of this practice the data existing have been recopied many times, so that I will not take space to recopy any of them, but wish to draw a few points from them, to bring out features of my discussion.

The question may be asked, "Is coke a satisfactory reducing agent, for use in the electric smelting furnace?" This question may be answered both in the positive and in the negative.

To answer in the positive, it may be stated that coke is satisfactory as a reducing agent. It contains a sufficient percentage of fixed carbon; is of sufficient crushing strength to withstand the ore column of the charge; reduces the metallic oxides to their metals; its fixed carbon is dissolved by the metal, where necessary, as in the manufacture of pig iron.

To answer in the negative, it may be stated that the carbon in coke is too dense; is somewhat refractory in the electric furnace oxidation, by the chemically combined oxygen in the ore; makes undesirable electrical conditions; causes too high electrode losses in the furnace; has the tendency to form high fusing carbides with the lime, when running on high lime slags; sows the furnace; crusts the furnace between electrodes.

These latter features are some of the factors militating against the use of coke as reducer in the electric smelting furnace. To cite more fully the conditions of the electric smelting process, in which I used coke as the reducer, I desire to state that the furnace was running on manganese ores with a high silica content; the coke carried 14 per cent ash; high sulphur content in the coke; the iron ores were pure magnetites and low in silica, but necessitated a limy slag to eliminate the high sulphur of the coke; the furnace was a three-phase furnace, with four electrodes in a straight line; the furnace was run with high charging stacks for feeding the charge; the furnace was run without the charging stacks; the furnace was run with deep crucible

and high bosh; the furnace was run with shallow crucible and high bosh. This gives the general conditions attending the operations of the furnace using coke as the reducing agent.

My views and conclusions on this subject have originated from personal experiences with various ores and reducing agents in the electric smelting of iron ores and manganese ores, producing pig iron, and 80 per cent ferromanganese.

Primarily, with some diversion, it might be well to investigate the physical and chemical properties of coke, to endeavor to fix the property or properties which contribute to the points mentioned.

Specific Gravity: Coke per unit of volume is two-and-one-half times heavier than charcoal. It will weigh from 25 to 30 lb. per cubic foot, depending on the grade and the manufacture. This point is important in the electric smelting process.

Porosity: Coke is very porous, having a large part of its total volume made up of cell space. This property is very beneficial in the blast smelting of ores with coke. This is not so pronounced in its use in the electric furnace.

Crushing strength: Nearly all grades of coke are possessed of a crushing strength sufficient to support the ore column of the electric furnace, where short ore columns are used generally.

Volatile matter: This is usually low in cokes, not exceeding two or three per cent.

Hardness: Most metallurgical cokes are hard enough to resist abrasion in handling. This is of importance, so that the coke does not become comminuted in handling, before reaching the furnace.

Physical state of carbon: The fixed carbon in the coke is in the form of a dense, hard structure in the mass forming the walls to the cell structure. This form of the carbon is quite refractory to the process of oxidation taking place in the electric furnace. The carbon is oxidized, but not as rapidly as the carbon in charcoal, for instance. This physical form of the carbon appears to be the controlling factor for the action of coke, when used in the electric furnace.

EFFECT OF SPECIFIC GRAVITY OF COKE

From the foregoing properties of coke it is made apparent that two properties at least affect the use of coke as a reducing agent in the electric furnace. One is its specific gravity, and the other is the physical form in which its carbon is present. As regards its specific gravity, the coke which I used was not finer than 1 in. in size, from this to 1½ in. A cubic foot of this coke weighed 30 pounds (3 per cent moisture). The term specific gravity refers to the apparent specific gravity. The ratio of the coke to the ore in the charge was about 1 to 3 by weight. The ore in a single charge weighed 500 pounds and would run about 180 pounds per cubic foot. We have then approximately 2½ cu. ft. of the ore, and 5 cu. ft. of the coke. With this, in smelting iron ore for pig iron, there is a small weight of lime rock; and in smelting manganese ores for ferromanganese there is approximately 2 cu. ft. of lime rock on the charge. This latter makes the ratio of about 4½ to 5 of ore, etc., to coke, or the proportion of 1 to 1 nearly.

From this it is seen that the charge contains as much volume of material with a high resistance as it does of a material of a low resistance. In other words, the material with the high resistance takes a high voltage with a low current, and the material with the low resistance takes low voltage with high current. But it must be remembered that these materials are all mixed up in the charge, and do not occupy portions

of the furnace volume separately. So the result is a charge having a high resistance, making a high voltage necessary to overcome the resistance, with an uneconomical use of the electrical equipment.

This does not appear to be in harmony with the statements of Oedquist, brought out by J. Hården, in *METALLURGICAL AND CHEMICAL ENGINEERING*, February, 1914, pp. 82 et. seq. It is stated here that the conductivity of the coke is high, giving large current density and at lower voltage. This would be true providing the volume of coke in the charge would be sufficient to affect in this way the electrical conditions.

Now with charcoal the results are different. Charcoal weighs about $12\frac{1}{2}$ pounds per cubic foot. For the same weight as before we would have about $13\frac{1}{2}$ cu. ft. of charcoal. But charcoal is not as good a conductor as the coke is. In this case we have a ratio of ore, etc., to charcoal of $4\frac{1}{2}$ to $13\frac{1}{2}$, or about 1 to 3. Under these conditions, when the charcoal is heated the charge contains enough carbon to make it a conductor of the current down into the furnace, where the resistance heating is brought into effect. In the upper zones of the furnace all the material is acting as a resistance to the current. But by the downward movement of the charge this material is soon heated in its passage down into the smelting zone, and in being heated acts as a conductor for the current to the slag and the molten resistor below. In this way the temperature of the crucible is maintained at the melting temperature for the metal and slag produced.

The action of coke as a conductor, hot and cold, can be seen in starting up a furnace. The furnace was filled about 18 in. deep with coke, and the electrodes put into this about 10 in. The main furnace switch was closed, and the voltage run up to 80 volts, which was the maximum voltage used on the variable-voltage transformers.

For the first three hours the load on the furnace would not be over 50 kw. for the first hour, up to about 200 kw. at the end of the third hour. After the fourth hour the load would increase to about 600 to 800 kw. and would be maintained there for the next three or four hours. As the coke mass became incandescent it would be possible to carry 1800 to 2000 kw. in the furnace. As the load increased the voltage decreased, until it was possible to carry 1200 kw. at 45 volts. At times the load would increase so fast that the minimum voltage (40 volts) was too high to maintain the load at 1200 kw., so the main switch was pulled to allow the coke to "cool off" for two or three hours. When the switch was closed again the load would come up to 1000 to 1200 kw. at about 50 volts. This is merely to show the electrical effect in using a high percentage of coke, in this case 100 per cent.

The same effect can be produced in using charcoal, but the action is slower; the charcoal oxidizes more rapidly and is soon consumed. However, when the charcoal is incandescent it forms a good conductor for the current. Eventually as the charcoal becomes incandescent, it presents the same phenomena as with coke, low voltage, high current.

In the electric smelting furnace almost any reducing agent will present difficulties. Various factors, relative to the electrical control of the furnace, are attributed to the conductivity or resistance of the reducing agents. Considering that the cheapest and most plentiful reducing agent is some form of carboniferous material, and that carbon in various forms is a good electrical conductor when hot and less so when cold, we would have certain electrical troubles with any of the available forms of carbon for a reducing agent.

In the upper part of a furnace, where the charge is not heated even to incipient fusion, any carbon material would not be as good a conductor as it would be when reaching a higher temperature in the lower highly heated parts of the furnace. Under these conditions coke and charcoal would act practically the same as they are admixed in the charge, although the coke has a lower resistance than the charcoal. It might be the view of a polemic, but in so far as the electrical conditions are considered in the electric smelting furnace, one reducing material acts with almost the same results as another.

Most of the investigators and writers on this subject have considered the properties of coke, electrically, in the electric smelting furnace, as being the same as though no other material were admixed with it, and the coke were free to act as a conductor, unhindered by the presence of a highly insulating material, as ore and limerock, mixed throughout the coke lumps.

My previous illustration of starting a furnace on a bed of coke and heating the coke with the electric current, should be contrasted with the other starting method of mixing complete charges and charging into the crucible of the furnace, putting the electrodes into it, and "juicing in." By using the latter method, a higher voltage is necessary, with a considerably longer time to heat the charge. It shows the effect of the raw ore, etc., on the conductivity of the charge, and the masking of the conductivity of the coke. Here the size of the coke lump would be important. The larger the lumps the lower the resistance of the charge, and vice versa.

Furthermore, with the use of the coke, the method of feeding the furnace does not materially change the conditions. The coke may be fed first, and the ore charge following; it may be fed around the electrodes and the charge fed clear of the electrodes; it may be fed mixed with the charge and all fed at one time in the proper proportions for the smelting process. The ultimate electrical conditions prevail, and the metal output, and power conditions do not show any marked results that can be attributed to the change in feeding the materials.

Crawford, in his work at Heroult, says in Bulletin No. 90 of the American Institute of Mining Engineers that he used crushed coke, because with the coarse coke, the furnace made melted oxides instead of pig iron, and by crushing the same coke to 1 in. size, the furnace made normal foundry iron. The decrease in the size of the coke lump would undoubtedly make the charge somewhat denser, thus increasing its resistance. This might have made a hotter furnace, thus bringing about the more complete reduction he mentions, by making normal foundry iron. The coarse coke refers to sizes larger than $2\frac{1}{2}$ in., and the fine coke refers to 1 in. to $1\frac{1}{2}$ in. size.

The summary of the discussion by Hården of Oedquist's paper, referred to previously, brings out the fact that the coke has a low resistance, and does not offer enough resistance to the charge to heat the smelting zone to a sufficient temperature. It is not this lack of resistance, but in my opinion too much resistance in the charge that causes the insufficient heating. This, of course, applies to the voltages operating on, and voltages that are practicable and applicable to the electric smelting furnace.

EFFECT OF STRUCTURE

The question of the use of coke has another phase, which is a chemical one. As stated previously in this article, the carbon is in a dense hard form. In this form it is quite resistant to oxidation, unless the oxygen is forced into the cell structure and can act on the

large area of structure exposed. In the open air, coke burns with considerable difficulty.

Consider then in the electric furnace, the coke in contact with the metallic oxides, with lime, silica, alumina, magnesia, and with other of the less abundant oxides, and silicates in the ore and fluxes. As the coke is carried down in the furnace, by the downward movement of the ore column, it comes into the zone of temperature at which its carbon will react with the oxygen of the ore and form carbon monoxide, and the metal will be reduced. Also at the temperature of the arc, some carbon comes in contact with lime, alumina, magnesia, and reduces these oxides also. In this reaction the infusible carbides are formed. According to the laws of thermochemistry that reaction which takes place at the highest temperature will be the ultimate reaction. In the zone of the electric arc, in the buried arc-resistance furnace, we have the highest temperature attainable. At this temperature the ultimate reactions take place, resulting in the formation of those compounds which have the highest melting points.

To avoid further argument I have used the term "buried arc-resistance furnace" in the above paragraph. The large smelting furnace in my opinion is a combination of the buried arc with resistance heating. The arc forms from the electrode to the materials in contact with the electrode. By so heating the materials around the electrode, the incandescent mass eventually acts as a conductor from one electrode to another, and the mass of materials is then heated by resistance; the hot materials in the fused and semi-fused states being the path of the current to the other pole of the circuit.

The occurrence of the formation of carbides, I consider to be the principal objection to the use of coke in the electric smelting furnace. The formation of carbides in the furnace puts an increased duty on the furnace. The presence of such material having a high melting point soon makes the furnace run irregularly by the increased melting temperature of the material it must melt, other than that for which it was designed.

The "sowing" in the furnace is soon evidenced by the elevated bottom; temporary loss of control of the product; increased power consumption; high electrode consumption; slowing up of the rate of smelting. The accretions formed in the furnace are due to the formation of the carbides. As the carbide accumulation grows gradually, the furnace is checked in its operations, as a consequence of the heat absorption by their formation. The walls of the furnace become crusted in their lower portions. The crusting along the side walls soon forms a scaffold for the charge to hang up on, and ultimately a bridge is formed across the furnace, and holds up the entire charge above it. The material beneath the bridge will melt out, leaving the superimposed charge hanging, until eventually it will slip down. As the charge comes down, the immediate result is a broken electrode or two.

TWO DIFFERENT FURNACE DESIGNS

Now with two different types of furnace, the effect of this bridging and sowing varies with the type of furnace. In the shaft and stack type of furnace, the hanging up seems to be more marked than in the low, stackless furnace.

In the electric smelting of iron ores for the production of pig iron in the shaft and stack furnace, the hanging up in the stacks appeared to be the greatest difficulty in the operations. In this smelting the furnace was run on a high lime content in the burden to eliminate a high content of sulphur in the coke. The furnace was a covered furnace having the electrodes

between the stacks, making five stacks and four electrodes. The mixed charge was dumped into the stack and the stack closed at the top, leaving only enough opening for the gases to burn freely.

With this furnace no definite knowledge was ascertained of the conditions in the furnace, other than the indirect pointers obtained from broken electrodes, and hot arches, and hanging up in stacks. It was evidenced though, that something was wrong, by the slowing up of the rate of smelting, and the slow rate at which the furnace took the charges. By "barring down" through the stacks with 16 lb. rails sometimes the bridge was broken and would fall. Other times this was no relief, and a stack was often left dead for several days, until it might open up when the furnace would work around in shape.

These bridges formed at the base of the stack, and just around the electrodes. The electrode would enter through one of these crusts through a hole about 12 in. larger than the diameter of the electrode.

Of course, this fact was not found out until after the design of the furnace had been changed, and such things could be observed and studied. With the formation of the crusts and bridges in the furnace the sow in the bottom of the furnace was forming also. This sow was not always a carbide sow, but contained considerable pig metal, which froze up as a result of being too good a conductor, when carrying current. But the cause of these conditions was primarily due to the falling off of the furnace load, as a result of the accretions and sow in the furnace.

In the other type of furnace, in which no stacks were used, and the furnace was run with an open top on manganese ores, the conditions mentioned above did not hold the same. In the absence of the high stacks, the charge had no place to hang up where it could not be got at to remedy by mechanical or hand power. The furnace was charged all over the top, and the charge was constantly stoked, to keep it from forming wall accretions, and the troublesome crusts. Whenever a sow was forming in the furnace bottom it could be known soon enough and remedied by adding oxidizing charges or by running the charge down and cutting out the sow with ore charges, or with fluorine slags. In this case the charge carried a high content of lime to make a limy slag, while running on high silica manganese ores.

It can be seen that with the two types of furnaces mentioned different results are obtained in their operations on coke. The furnace that can control the erratic and irregular conditions while using the coke reducing agent would appear to be the furnace to adopt for the smelting with coke, and with a slag that is to run at least 40 per cent to 45 per cent lime, making the burden on the furnace strongly basic.

It might be of interest to give briefly the operations attending the use of coke in the furnace of the stack type.

The coke analyzed as follows:

Proximate analysis:	Per Cent	Ash analysis:	Per Cent
Moisture	3.00	Silica	63.50
V. C. M.	3.50	Alumina	15.70
F. carbon	79.50	Lime	2.50
Ash	14.00	Magnesia	0.90
Sulphur	1.11	Sod. oxide	5.40
Phosphorus	0.35	Pot. oxide	12.30
		Ferric oxide	12.30

The coke was crushed to pass a 1½-in. ring. Before going to the furnace the coke was screened over ½-in. openings in a revolving trommel. In using this coke a basic slag was carried, running about 42 per cent to 45 per cent lime. These operations were carried out on the smelting of a pure magnetite ore, producing pig iron.

During the period of these operations (about 90 days) the furnace gave incessant trouble with crusts, hang ups, broken electrodes, slipping of the charge, burned out arch roofs, cold bottom, no taps at the regular time of taps, lower silicon iron than desired, and for which the charge was calculated, and loss of lime in the furnace "somewhere." It must be understood that these troubles did not all accumulate every day, but during the run they were enough in evidence to show that the furnace was not the commercial article yet for running with coke, and that the black horse factor causing all or part of the trouble had not been brought to light.

But considering that satisfactory operations in this furnace had been conducted with charcoal as the reducer, it led me to study the coke operations and to lay the trouble to the use of coke. It would be invaluable here to give power data, and other data on these operations in more detail, but at the present writing I am not possessed of such data. The grade of iron made varied from 0.70 per cent to 3.00 per cent silicon; from 2.70 per cent to 3.50 per cent total carbon. The iron was rather high in sulphur, running from 0.023 per cent to 0.326 per cent, of course depending on the working of the furnace.

To sum up the operations, I did not consider them in any way successful operations in the type of furnace used, with the use of coke as the reducing agent, with basic limy slag.

Crawford, in the same article referred to previously, says that any grade of coke can be used by crushing it. He also says that "black butts," screenings, can be used. I do not consider any material but the cleanest to be most desirable for the electric furnace, and the process will never be established or proven successful with the use of poor materials. We used some screenings at that time, and they were the poorest material that could be found, high in ash, low in carbon, high in sulphur and phosphorus. It might be stated here that with the best coke obtainable and with the exceptionally pure magnetite ores obtainable and smelted at that time, the coke smelting might have been nearer to a commercial success. I say this from a full knowledge of the conditions referred to above, as I was actively connected with the operations.

To go further. Assume that the furnace is running normally, and an excess of carbon accumulates in the furnace. As can be readily expected, a mass of carbides will form from the excess carbon and a carbon freeze up takes place. But in the discussion on the use of coke, it is considered that the carbon being supplied by the coke is in the proper proportions to make the proper reactions take place, providing no contrary reactions hinder the former.

In the formation of carbides, another feature presents itself. The slag control is very difficult, due to the use of the lime in combining with the carbon to form calcium carbide. This molten carbide acts very corrosively on the electrodes (graphite) and increases the consumption to a prohibitive figure.

In the absence of high percentages of sulphur in the coke, high silica in the ores smelted, and the use of a slag with a low lime content, allowing the slag to run higher in silica, so as to have the slag nearly neutral or acid, it should be possible to run with coke and not have the attendant difficulties mentioned when running on a high lime burden.

This discussion is not written for the purpose of condemning the use of coke in the electric furnace. But under the conditions cited, coke does not appear to give a satisfactory, continuous, economical smelting operation.

Eventually as the supplies of timber for making char-

coal will become depleted and exhausted, resort will be necessarily had to coke or some other form of carboniferous reducing agent. In order to develop this industry, and to broaden the scope of the electric smelting furnace in the production of pig iron, principally basic and foundry, the experiences of operators in published accounts will aid in developing the process and establishing the proper conditions for the electric smelting process using coke as reducer.

Los Angeles, Cal.

X-Rays and Crystal Structure with Special Reference to Certain Metals

On the occasion of the sixth annual May lecture of the (British) Institute of Metals, delivered on May 4, at a meeting of the Institute in London, Prof. W. H. Bragg, D.Sc., F.R.S. (Nobel Prizeman) gave an interesting account of the new method of applying the properties of X-rays to the study of crystal structure, including the structure of certain metals.

The method, it was shown by the professor, results in the determination of the exact relative positions of the atoms of which the crystal is composed. It is not successful in every case as yet because of the lack of practice and experience of the experimenters in the new field and because some of the interpretations are not fully understood. There is no lack of indications: but we are not yet fully aware of the meaning of all of them.

It is natural to attack first such crystals as have an obviously simple structure and consist of few elements associated in simple proportions. It is also of great advantage if the crystals belong to a group of isomorphous members, such as the rock salt series. This series, in fact, has everything to recommend it to the experimenter: its form is simple, that of the cube; its symmetry is high; it contains two elements only, in equal proportions, *e.g.*, sodium or potassium associated with chlorine or iodine; and there are several members of the series so that we can watch the effect of changing one element at a time. The constitution of this series was, therefore, one of the first to be examined and made plain.

The constitution of the diamond, which has also been determined, presented a rather more difficult task, because the arrangement of the atoms is not so simple as that of the rock salt series, although its form is cubic, its symmetry is high and it contains atoms of one kind only.

Of the metals which will naturally be of especial interest to the Institute of Metals, silver and copper, and by inference gold, have been shown to possess a very simple structure, in which the atoms are arranged as in the piling of shot. Bismuth and antimony have a distorted arrangement; but these two, as well as zinc, have not been completely determined. A beginning had been made with iron. The war has, however, stopped all work of the kind on this metal.

This new field of research, according to Professor Bragg, depends on a principle already known. When a regular train of waves falls upon a surface separating two media, part is reflected and part goes on. If the part that goes on meets another separating surface, a second portion is reflected and some of this emerges from the second medium in the same direction as the beam reflected from the first surface. It will happen in general that the two reflected beams are out of phase and to that extent destroy one another. Whether they do or not depends upon the relation between the wave length, the angle of the inclination of the beam to the reflecting surfaces, and the distance between the surfaces. In this way are explained the colors of the soap

film, of the thin layer of oil on the surface of a liquid, of the colors of steel when being tempered and so on.

If the reflecting surfaces are many in number, not two, the effect is made more intense and at the same time more precise. It occurs in the beautiful colors of potash crystals as shown by Lord Rayleigh. These crystals are formed of alternating layers, twinned across their surfaces of separation; and for some obscure reason the thickness of all the layers is the same though it varies from crystal to crystal. When white light containing all wave lengths is incident upon such a crystal, at a certain angle, then only that wave length is reflected for which the proper relation between the wave length, angle, and spacing holds good. If the angle is altered the wave length which is reflected is no longer the same. Hence the beautiful play of crystal colors.

It is an essential cause of success that the wave length and the spacing are not very different in amount.

We now pass on to the case of the X-rays. These consist of waves—so indeed these very experiments tell us—which are something like 10,000 times shorter than the wave length of light. To obtain the parallel effect we must look for reflecting surfaces which are 10,000 times closer together than the twinning surfaces of the chlorate of potash crystals, and these are separated from one another by only the 40/1000 of an inch or thereabout. These also Nature has provided in the layers of atoms in the crystal.

It may seem curious that a layer of atoms should act as a reflecting surface; but after all it is not necessary that such a surface should be continuous. A row of iron railings, for example, can act as a reflector of sound waves. A natural face of a crystal contains no doubt a layer of atoms arranged regularly; and behind the natural face are other layers all similar, and placed at regularly increasing distances behind it. Thus all the conditions for this peculiar reflection experiment are present, and we actually find that when a pencil of X-rays of a definite wave length are allowed to fall upon the face of the crystal, and the crystal is gradually turned round so as to alter the angle of incidence, the reflection of the beam as a whole is non-existent except when the angle is right. Then it flashes out strongly. When this angle is observed, the relation of the wave length to the spacing is known.

The instrument used is called the X-ray spectrometer. It has no lenses because X-rays cannot be refracted; and the rays are invisible so that in place of the telescope appears a chamber containing gas which is ionized by the X-rays. The resulting electrical effect is observed in an electroscope. It is important that the measurement of the result is quantitative so that in this respect the new spectrometer has an advantage over the old.

In this way if we use always the same X-ray we can compare the spacings between the layers parallel to one after another of the natural faces parallel to the crystal; and in this way we arrive finally at the crystal structure. The instrument is not at all difficult to use, and the observed effects are large and precise so that it is quite easy to get numerical results. The interpretation is not always quite so easy. One part of it comes readily, viz: the number of molecules to each unit of the pattern of the crystal—the unit being the smaller part which being reflected again and again without alteration or orientation or distance from its neighbors forms the complete crystal. For instance, the unit of pattern of potassium sulphate contains four molecules; the unit of pattern of antimony contains two atoms.

The far greater difficulty lies in the determination of the way in which the atoms are arranged in the unit. These data are sufficient, but the interpretation is hard.

The Distribution of Silver Between Metallic Lead and Litharge-Containing Slags

BY BOYD DUDLEY, JR.

(Concluded from page 641)

The Effect of Litharge

The positions of the curves in Fig. 3 indicate that for a given temperature there is a close and consistent relationship between the percentage of litharge in the slag and the ratio of equilibrium concentrations. As the percentage of litharge increases the concentration ratio decreases, indicating that the power of the slag to retain silver in the presence of metallic lead increases with increasing litharge content. This is in agreement with the prevailing idea that high litharge slags retain more silver than do low litharge slags. To so state the proposition is qualitatively correct, but the data at hand provide further information and show that the dissolving power of the slag for silver is almost, if not entirely, due to its litharge content.

In connection with the foregoing it seems advisable to particularly emphasize the fact that all data herein presented are in terms of unit quantities of slag and metal. The logical way in which to view the question of slag losses is with reference to the amount of slag as compared with the amount of lead. If two assays are made on equal quantities of an ore with slags of the same composition and with the same amounts of lead reduced in each, but with twice as much slag in one as in the other, it seems obvious that, under given temperature conditions, the total silver retained by the first slag will be approximately twice that retained by the second. However, in spite of the self-evident nature of this proposition the effect of quantity of slag upon slag losses in assaying has been quite generally disregarded by writers on this subject. When it is thoroughly understood that a true chemical equilibrium is involved, it becomes clear that the total quantity of silver retained by the slag will be proportional to the quantity of slag produced, other conditions being constant.

To bring out most clearly the effect of various percentages of litharge upon the ability of the slag to retain silver it is necessary to calculate the molecular percentages of litharge in the various slags, and to compare these with the reciprocals of the equilibrium concentration ratios. The importance of the litharge content is evident from Fig. 3, but its effect upon the retention of silver by the slag is not proportional to the percentage of litharge by weight. A brief consideration of this point will show that such a rela-

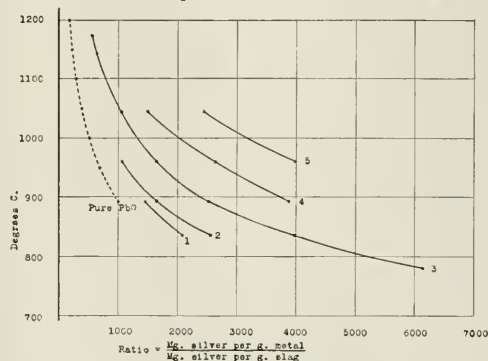


FIG. 3—EQUILIBRIUM CONCENTRATION RATIOS

tionship is not necessarily to be expected, because whatever effect the litharge may exert in the way of dissolving silver will probably be produced by molecules of litharge and not by grams of this material. Consequently, the concentration of the molecules of litharge in the slag with reference to the other molecular species that may be present, rather than the weight percentage of the litharge, is to be considered.

The concentration ratios given in the preceding tables and plotted in Fig. 3 are measures of the ability of the slags to retain silver, but their reciprocals provide a more direct measure. The reciprocal of the concentration ratio represents the concentration of the silver in the slag when its concentration in the metal, with which the slag is in contact, is unity. The reciprocal provides, therefore, a direct measure of the dissolving power of the slag for silver in the presence of metallic lead.

Table VII has been constructed to show the relation of the molecular percentage of litharge to the dissolving power of the slag for silver. In it the reciprocals of the concentration ratios have been multiplied by 10,000 in order to avoid the use of very small fractions. The molecular percentages of the litharge were calculated from the analyses of the slags shown in Table II by the customary method.

TABLE VII.—RECIPROCAL OF CONCENTRATION RATIOS $\times 10,000$ IN RELATION TO TEMPERATURE AND MOLECULAR PERCENTAGE OF LITHARGE

Slag No.	Weight, Molecu- lar, Per		Reciprocals of Concentration Ratios $\times 10,000$					
	PbO Cent	Pb Cent	837°	892°	960°	1045°	1143°	1173° C.
1	89.7	71.1	4.81	6.90	...	...	...	...
2	85.6	61.7	3.92	6.16	9.44	...	...	...
3	71.7	41.4	2.52	3.98	6.10	9.52	16.00	17.90
4	48.3	20.4	...	2.58	3.80	6.71	...	...
5	24.9	8.4	...	...	2.50	4.12	...	...

Fig. 4 shows the data of Table VII plotted to scale with molecular percentages of litharge as abscissas and reciprocals of concentration ratios multiplied by 10,000 as ordinates. It is seen that, within the limits of experimental error, the ability of the slag to retain silver in the presence of metallic lead is found to be a direct function of the molecular concentration of the litharge present. It appears that with no litharge present in the slag, i.e., with a slag composed of silica,

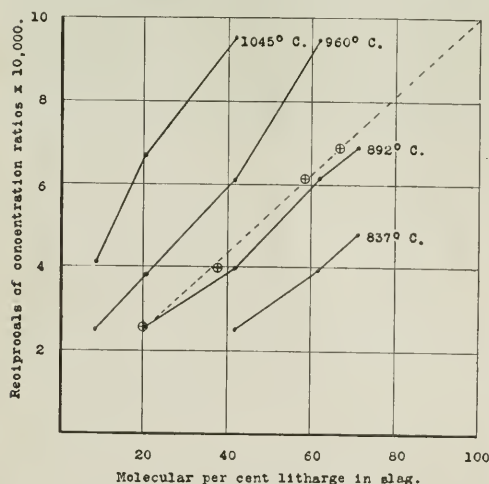


FIG. 4.—RECIPROCAL OF SILVER CONCENTRATION RATIOS $\times 10,000$ PLOTTED AGAINST MOLECULAR CONCENTRATIONS OF LITHARGE IN THE SLAGS

boric oxide, and soda, the amount of silver retained would be comparatively little, though as to the exact amount under such conditions the data are inconclusive.

The most important point shown by Fig. 4 is that at constant temperature the ability of such slags to dissolve and to retain silver is mainly dependent upon the molecular concentration of the litharge, and is independent of the so-called silicate degree or oxygen ratio of the slag. It will be noted that slags are represented that vary in oxygen ratio from 0.48 to 1.71, but that such variations fail to make themselves apparent. The obvious conclusion is that the molecule of litharge in igneous fusion with other molecules retains its specific properties to a sufficient extent to exert the same solution effect upon silver, whether it is associated with few or many molecules of other kinds. In other words, such slags may perhaps be better regarded as simple solutions of various oxides dissolved in each other than as solutions of associated compounds that might be formed by the combination of these oxides.

In considering the data presented in Table VII and in Fig. 4, it is necessary to bear in mind that the litharge concentrations specified are calculated from the original constituents added to the crucible charge. It has been previously noted that the slags resulting from these fusions contain less litharge than the calculations would indicate. This is largely on account of the dilution of the slag caused by corrosion of the crucible and stirrer while the slag is in contact with them. In general, the departure of the litharge content of the slag obtained from the calculated figure increases with increasing temperature and with increasing litharge concentration in the slag. Consequently, it can be said that the positions of straight lines drawn in Fig. 4 to show the effect of litharge concentration upon silver retained at various temperatures should be somewhat higher and have a greater slope than those shown. However, the lines that are shown are perhaps as useful in regard to practical conditions as would be those occupying the precisely correct positions, because the ones shown actually represent results secured when certain charges are compounded and fused in clay crucibles, thus allowing for the dilution of the slag that necessarily accompanies this most customary procedure.

Losses of Silver in Cupellation

On the other hand, if the true litharge content of the slag at the end of the experiment is known, the relationship shown by Fig. 4 will provide a fairly accurate means of estimating by extrapolation the ability of pure litharge to retain silver in the presence of metallic lead. Such information is of much interest in connection with the subject of cupellation. Whether the process is being employed for determinative purposes, or for the purpose of separating silver from lead on a large scale, the litharge produced by the oxidation of the lead is formed as a fairly thin film over the surface of the molten alloy undergoing cupellation. Owing to the comparative thinness of the litharge film, to its fluidity, and to its movement over the surface of the molten alloy, the litharge has an excellent opportunity to dissolve that amount of silver which it is able to retain under the existing conditions of alloy composition and temperature. In other words, the chances for establishing equilibrium between the litharge and the metal are good. This is probably particularly true of cupellation on a small scale for determinative purposes, the film of litharge under these conditions being extremely thin.

The litharge formed at any instant flows from the surface of the metal and carries with it the silver that it has dissolved, the concentration of silver in the

litharge being dependent upon its concentration in the metal and upon the temperature at the surface of the metal where the oxidation occurs. As the concentration of the silver in the metal increases its concentration in the litharge will increase, hence the loss of silver will be greater toward the finish of the cupellation. Of course, the loss of silver due to its solution in the litharge is not the only loss occurring during cupellation. Unquestionably some silver is removed from the cupel by volatilization, and probably some of the silver-lead alloy is absorbed as such by the cupel. But the loss due to the dissolving power of the litharge for silver is in most cases fully as important as are all of the others taken together. Therefore, a study of the available information in regard to the nature and magnitude of this loss appears to be worth while.

Dissolving Power of Pure Litharge

The importance of determining the actual litharge content of the slag at the conclusion of each experiment was, unfortunately, not recognized at the time the work was done, and samples of the slags were not saved. It was not foreseen that the results of experiments with litharge-containing slags could be extended to yield information concerning the properties of pure litharge. In order to determine the approximate compositions of the slags actually produced from the crucible charges, a number of fusions of slags 1, 2, 3 and 4 were made in duplicate at 892 deg. C. The charges were prepared, fused, held at constant temperature, and stirred for the same time and in the same way as was the case during the previous experiments. The slags were then analyzed for lead. By assuming the variation of the litharge content of the slag as actually produced from its calculated composition to be caused by dilution of the slag with clay from the crucible and stirrer, the approximate molecular composition of the slag secured can be calculated. The clay dissolved consisted of silica and alumina in almost equal parts, hence the average molecular weight of the diluent is approximately 80. The increase in weight of the slag corresponding to the difference between the calculated litharge content of the slag and that actually observed is therefore produced by dilution with substances having this average molecular weight. From the analyses of the slags as obtained, and from the compositions calculated from the reagents employed, the molecular percentages of litharge in the slags produced can be calculated by the usual methods.

Table VIII shows the results of analyses and the molecular percentages of litharge in the slags actually produced. Averages of two analyses are given for each slag.

TABLE VIII.—MOLECULAR PERCENTAGES OF LITHARGE IN SLAGS PRODUCED AT 892 C.

Slag No.	Calculated Wt. Per Cent PbO	Obtained Wt. Per Cent PbO	Dilution by Clay, Wt. Per Cent	Calculated Mol. Per Cent PbO	Obtained Mol. Per Cent PbO
1	89.7	87.1	3.0	71.7	66.7
2	85.0	82.7	2.8	61.7	58.4
3	71.7	68.9	4.1	41.4	37.6
4	48.3	47.9	1.0	20.4	20.2

The greatest dilution was experienced by slag No. 3, which is both less basic and contains less litharge than slags No. 1 and No. 2. The reason for this is that the time during which No. 3 was in contact with the crucible and stirrer was nearly two hours, while No. 1 and No. 2 were in the furnace only about one hour.

The molecular percentages of litharge in the slags as they were actually obtained have been plotted in Fig. 4 against their corresponding reciprocals of concentration ratios. The dotted straight line drawn through these points represents the true relationship between

the ability of the slag to dissolve and to retain silver in the presence of metallic lead and the molecular concentration of litharge in the slag. This line represents the conditions at 892 deg. C. By extending it to the line on the diagram representing 100 molecular per cent of litharge, the probable dissolving power of the pure material for silver at this temperature will be obtained. The point of intersection of the dotted line with the 100 per cent litharge line is approximately 10, as measured by the scale of the axis of ordinates. Since the ordinates in this figure are the reciprocals of concentration ratios multiplied by 10,000, the ratio of the equilibrium concentrations of silver in lead and in pure litharge at 892 deg. C. is found to be

$$\frac{1}{10} \times 10,000 = 1000.$$

That is, with lead and pure litharge in contact at 892 deg. C., and with silver distributed between them, the concentration of silver in the metal will be 1000 times as great as its concentration in the litharge, unit weights being considered in each case.

Equilibrium with Rich Silver-Lead Alloys

All of the concentration ratios that have been previously presented are in terms of mg. of silver per g. of metal divided by mg. of silver per g. of slag. If weight percentages were employed the results would be the same. Such ratios will correctly represent equilibrium conditions so long as the concentration of silver in the metal remains below about 10 per cent by weight. Such high concentrations are, of course, not ordinarily encountered in the crucible fusion, so for purposes of indicating the magnitude of slag losses in this process the figures given are entirely sufficient. But in extending the results to cover the case of pure litharge, and to indicate the loss of silver during cupellation, the question naturally arises as to what the equilibrium conditions are when litharge is in contact with silver-lead alloys of greater richness than 10 per cent silver by weight.

In order to determine this point a series of experiments was performed, in which slag No. 3 was held in contact at 837 deg. C. with alloys containing 30, 50 and 70 per cent of silver by weight. The method of procedure was the same as has been previously described. The results of these experiments are set forth in Table IX, in which the first line of figures relating to a 5-per cent silver alloy represents the average results previously secured with slag No. 3, and detailed in Table IV.

TABLE IX.—RESULTS WITH SLAG NO. 3 AND RICH SILVER-LEAD ALLOYS AT 837° C.

a	b	c	d
Wt. Per Cent Silver in Alloy After Experiment	Mol. Per Cent Silver in Alloy After Experiment	Mg. Silver per g. slag	Ratio c/d
5.0	9.2	0.0126	730
30.1	45.3	0.0592	765
29.9	45.0	0.0610	737
50.8	66.4	0.0923	720
50.1	65.8	0.0845	779
70.1	81.8	0.109	750
69.9	81.6	0.115	710

Note: The fusions were made in pairs, and in each case the equilibrium was approached from both sides. The slag assays given under "c" are corrected values, checks having been used with the cupellations.

When the weight percentages of silver in the alloy are considered in connection with the concentrations of silver in the slag, there is no apparent relationship. But when these weight percentages are calculated to molecular percentages, assuming that both metals are present in the alloy in the monatomic state, and divided by their corresponding concentrations of silver in the slag, a series of practically constant ratios is obtained. The variations between these ratios are not greater than might be expected, when the different sources of experimental errors are considered.

The results of experiments with the rich silver-lead alloys show that the equilibrium concentration of silver in the slag is directly proportional to the molecular concentration of silver in the metal rather than to the weight percentage of silver therein. This conclusion does not conflict with the results shown in Table IV, where it was seen that, between the limits of 2 per cent and 8 per cent of silver in the metal by weight, the equilibrium concentration of silver in the slag is directly proportional to the weight percentage of silver in the alloy. Simple calculations show that within these limits the ratio between the composition of the alloy by weight and its molecular composition is so nearly constant that the variation could not be detected by the methods of experiment employed. But when the concentration of silver in the alloy is increased beyond about 10 per cent by weight, the ratio between the weight percentage and the molecular percentage is altered to such an extent that the variation becomes apparent. It is unnecessary in any case to convert the silver concentration in the slag to terms of molecular concentration, because in all cases the slag is very dilute with respect to silver.

General Statement of Equilibrium Conditions

All of the foregoing facts and figures can be summed up in a single statement as follows: At a given temperature the equilibrium concentration of silver in a slag of the type that has been investigated is directly proportional to the molecular concentration of silver in the metal with which the slag is in contact, and it is also directly proportional to the molecular concentration of litharge in the slag. Expressed in the form of an equation this statement appears thus

$$\frac{\text{Mol. per cent silver in metal}}{\text{Mg. silver per g. slag}} = \frac{\text{Constant}}{\text{Mol. per cent litharge in slag}}$$

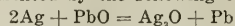
In the case of a given slag the molecular percentage of litharge is itself a constant, and, if the concentration of silver in the metal is not too great, the molecular percentage of silver in the metal will be proportional to the weight percentage. Under such conditions the above equation may be reduced to the form

$$\frac{\text{Mg. of silver per g. metal}}{\text{Mg. of silver per g. slag}} = K \text{ (a constant),}$$

which is the relationship originally determined and expressed in Tables IV, V, and VI.

In just what form the silver is present in the slag, and by what reaction its dissolution in the litharge is effected are points that at present cannot be definitely settled. It appears that the litharge is the most active of the slag-forming constituents employed in point of ability to dissolve silver. In fact, the other oxides entering into the constitution of the slags under consideration seem to have practically no power to dissolve silver and to retain it in the presence of metallic lead. From the relationship deduced in the preceding paragraph it might be said that the litharge possesses the ability to dissolve a definite quantity, expressed in molecular weights, of the silver-lead alloy with which it is in contact, and that this ability is independent of the degree to which the litharge may be diluted by other molecular species. If such is actually the case, then the observed variations of silver concentration in the slag with changing silver concentration in the metal and with changing litharge concentration in the slag are accounted for. On the other hand, the experimental results appear in many respects to indicate that the silver is dissolved by the litharge or slag in the form of

silver oxide, which may be produced by a reversible reaction represented by the following equation:



Supporting this theory is the fact that the litharge is the only readily reducible oxide present in the slag, and, therefore, the amount of silver oxidized and retained by the slag will depend mainly upon the amount of litharge present. Opposed to it is the experimental work of Lewis,² who has shown that silver oxide is a very unstable compound at elevated temperatures, it having a strong tendency to dissociate into metallic silver and oxygen. The dissociation tensions were found to be as follows:

Temperature, C.	Dissociation Tension in Atmospheres of Oxygen
302	20.5
325	32.0
445	207.

It is evident that the tendency of pure silver oxide to dissociate into metallic silver and oxygen at the temperature of the assay furnace would be measured in terms of thousands of atmospheres of oxygen. But it is entirely possible that the dissociation tension of this compound may be greatly depressed when it is present in very dilute form in a slag.

Which of the two proposed theories offers the correct explanation of the ability of the slags to retain silver the writer is not prepared to state. The experimental results point in part to each, and it may be that the litharge both dissolves a portion of the alloy as such and at the same time oxidizes a portion of the silver. Whatever may be the true explanation, the effect is found to be the same as might be predicted from the hypothesis that the litharge simply dissolves a portion of the alloy with which it is in contact.

Effect of Temperature on Dissolving Power of Litharge

It has already been shown that the probable ratio of equilibrium concentrations of silver in a dilute silver-lead alloy and in pure litharge at 892 deg. C. is 1000, concentrations by weight being considered. Several methods are available whereby this information may be extended to other temperatures. Probably the best way is to start from the point mentioned and construct a curve similar to those representing the various slags in Fig. 3. The necessary calculations for the construction of such a curve may be made with the aid of the van't Hoff equation,³ which is:

$$\frac{d \log_e K}{dT} = \frac{Q}{RT^2}$$

In this equation K is, in general, a mass action constant, which in the case under consideration is represented by the ratio of equilibrium concentrations of silver in the metal and in the slag; Q is the heat of reaction of the process as it takes place at the absolute temperature represented by T . More exactly, Q is the heat evolved by the reaction when a molecule of the reactant represented in the denominator of K is produced. If it is assumed that the litharge simply dissolves the alloy, then Q represents the heat of solution. The quantity R is the constant of the gas laws; its value is 1.985 g. calories.

The above is a differential equation, the integral of which is

$$\log_e K = -\frac{Q}{RT} + B,$$

where B is the constant of integration. If the values of K are K_1 and K_2 at the temperatures T_1 and T_2 , re-

²Journal Am. Chem. Soc., XXVIII, part 1, p. 139 (1906).

³Nernst, Theoretical Chemistry, Trans. 6th Ger. Ed., p. 654.

spectively, by substitution the two following equations are obtained:

$$\log_e K_1 = -\frac{Q}{RT_1} + B,$$

$$\log_e K_2 = -\frac{Q}{RT_2} + B.$$

Subtraction of the first of these from the second gives

$$\log_e K_2 - \log_e K_1 = \frac{Q(T_2 - T_1)}{RT_1 T_2}$$

Substituting for R its value, 1.985 cal., and employing logarithms to the base 10, produces the working equations,

$$\log K_2 - \log K_1 = \frac{Q}{4.571} \cdot \frac{(T_2 - T_1)}{(T_1 T_2)}$$

and

$$Q = \frac{4.571 (\log K_2 - \log K_1) (T_1 T_2)}{T_2 - T_1}.$$

In the above integration it is assumed that Q is independent of the temperature, which is not generally the case. But the experiments under consideration were not sufficiently exact to indicate the variations of Q with temperature, so the assumption that it does not vary is consistent with the general precision of the results.

By means of the integrated equation and the values of K for various temperatures a number of values of Q can be calculated, the average of which will provide a fairly correct average value for the heat-of-solution of silver in the slags over the range of temperature covered by the experiments. The method of calculation is illustrated by the following example. Experiments with slag No. 3 at 780 deg. and 837 deg. C. (1053 deg. and 1110 deg. absolute) show the equilibrium concentration ratios of silver in the metal and in the slag to be 6140 and 3980 respectively. The following substitutions in the integrated van't Hoff equation will yield the value of Q corresponding to these data:

$$\begin{aligned} T_1 &= 1053 \\ T_2 &= 1110 \\ K_1 &= 6140 \\ K_2 &= 3980 \\ \log K_1 &= 3.7882 \\ \log K_2 &= 3.6000 \end{aligned}$$

$$\frac{4.571 (3.6000 - 3.7882) 1053 \times 1110}{57} = -17,700 \text{ cal.}$$

Similar calculations have been made with the aid of all data contained in Tables IV, V, and VI. The resulting values of Q are collected in Table X.

TABLE X.—CALCULATED VALUES OF Q FOR ALL SLAGS AND TEMPERATURE RANGES

Slag No.	Temperature Range, C.	Calculated Value of Q
1	837 to 892	-16,800
2	837 to 892	-20,900
2	892 to 960	-18,200
3	780 to 837	-17,700
3	837 to 892	-21,500
3	892 to 960	-17,800
3	960 to 1045	-16,900
3	1045 to 1143	-19,500
3	1143 to 1173	-15,400
4	892 to 960	-16,400
4	960 to 1045	-21,600
5	960 to 1045	-18,900
Average value of Q =		-18,500 cal.

The fact that no consistent relationship between the heat of reaction and the composition of the slags is disclosed by the twelve values of Q thus obtained constitutes additional proof of the proposition that the same reaction, whatever its nature may be, is responsible in each case for the transfer of silver from the

metal to the slag, or the reverse. Therefore, it appears safe to assume that the figure — 18,500, representing the average heat-of-reaction found in Table X, will apply when the slag consists of pure litharge as well as when it is a solution of litharge in other oxides. With the aid of this assumption the equilibrium concentration ratio at any temperature of silver in silver-lead alloys and pure litharge may be calculated from the previously obtained value of 1000 at 892 deg. C. See Fig. 4.

For example, to calculate the concentration ratio at 950 deg. C. for silver in dilute silver-lead alloys and pure litharge, the following substitutions are made in the integrated van't Hoff equation:

$$\begin{aligned} \log K_1 &= \log 1000 = 3.0000 \\ T_1 &= 892 + 273 = 1165 \\ T_2 &= 950 + 273 = 1223 \\ Q &= -18,500 \\ \log K_2 - 3.0000 &= \frac{-18,500 (1223 - 1165)}{4.571 \times 1165 \times 1223} \\ \log K_2 &= 3.0000 - 0.1646 = 2.8354 \\ K_2 &= K_{950 \text{ deg.}} = 685. \end{aligned}$$

Similar calculations have been made for temperatures above 950 deg. with results as shown in Table XI. The calculated values are plotted to scale in Fig. 3 with a dotted line drawn through the points.

TABLE XI.—EQUILIBRIUM CONCENTRATION RATIOS OF SILVER IN DILUTE SILVER-LEAD ALLOYS AND PURE LITHARGE AT VARIOUS TEMPERATURES

Temperature, C.	Ratio = $\frac{\text{Mg. of silver per g. of metal}}{\text{Mg. of silver per g. of litharge}}$
892	1000
950	685
1000	507
1050	385
1100	298
1150	235
1200	188

The concentration ratios thus obtained represent with fair accuracy the equilibrium conditions so long as the concentration of silver in the metal remains below about 10 per cent. Above this point another set of values is required, because the concentration of silver in the litharge is in reality proportional to its molecular concentration in the metal rather than to its weight concentration therein. Accordingly, a set of ratios has been calculated which represents the relationship between the molecular percentage of silver in the metal and the mg. of silver per g. of slag at various temperatures. In order to calculate such a ratio assume a concentration of silver in the metal equivalent to 40 mg. per g., or 4 per cent by weight. This corresponds very closely to the composition of the alloys employed in most of the slag experiments. The molecular percentage of silver equivalent to this weight percentage is 7.40. From Fig. 3 it is seen that at 900 deg. C. the ratio of equilibrium concentration of silver in the metal and silver in pure litharge is 950, weight concentration being considered. The corresponding concentration of silver in the litharge will be

$$\frac{40}{950} = 0.0421 \text{ mg. of silver per g. of litharge.}$$

The desired ratio of molecular percentage of silver in the alloy to concentration of silver in the litharge may now be obtained by division,

$$\frac{7.40}{0.0421} = 176.$$

Ratios corresponding to other temperatures have been calculated. The resulting values are given in Table XII, and are shown plotted to scale against their corresponding temperatures in Fig. 5.

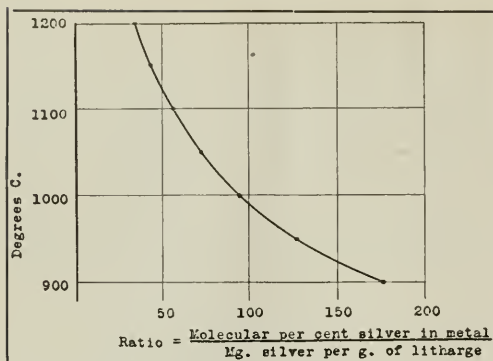


FIG. 5—EQUILIBRIUM CONCENTRATION RATIOS OF SILVER IN SILVER-LEAD ALLOYS AND PURE LITHARGE AT VARIOUS TEMPERATURES

To facilitate the use of Table XII Fig. 6 is provided, which shows the relation between molecular and weight percentage in silver-lead alloys.

The ratios of molecular per cent of silver in the metal to mg. of silver per g. of litharge may apparently be relied upon to indicate with reasonable accuracy the equilibrium conditions at various temperatures when pure litharge is held in contact with silver-lead alloys

TABLE XII.—EQUILIBRIUM CONCENTRATION RATIOS OF SILVER IN SILVER-LEAD ALLOYS AND PURE LITHARGE AT VARIOUS TEMPERATURES

Temperature, C.	Ratio = Molecular per cent silver in metal Mg. of silver per g. of litharge
900	176
950	127
1000	94
1050	69.5
1100	55.2
1150	43.6
1200	34.8

of compositions up to 70 per cent silver by weight. Experimental work with the slags has not been carried beyond this point. Therefore, positive evidence in regard to more concentrated alloys is lacking. But various records of cupellation in the English type of cupelling furnace show that the concentration of silver in litharge from rich bullion is generally much higher than the ratios of Table XII would indicate. However, in comparing these ratios with any figures from practice it should be remembered that they are supposed to indicate the concentration of silver actually dissolved in pure litharge, when equilibrium has been established between it and the metal with which it is in contact.

The litharge made in the cupellation furnace is generally not pure, but contains oxides of other metals in various amounts. These oxides may exert a greater dissolving action upon the silver than would an equal amount of pure litharge, and owing to this fact the dissolved silver in furnace litharge may be higher than the above equilibrium ratios would indicate. A part of the silver contained in cupel furnace litharge is almost invariably present as minute shots of the silver-lead alloy mechanically carried, and some of the high assay values of furnace litharges are doubtless due to this fact. These points should be taken into consideration when the equilibrium ratios of Table XII are compared with data from practice.

In addition to the above reasons why furnace litharge may be much richer in silver than the concentrations corresponding to the ratios in question, there is another possible explanation, which should not be overlooked. If all or a considerable part of the silver is held by the slag or litharge in the form of silver oxide, then it is

entirely possible that, when a rich silver-lead alloy is subjected to rapid oxidation, the litharge as it is first formed may contain a much greater amount of silver than corresponds to the equilibrium concentration. If there is intimate contact between the metal and the litharge for a sufficient length of time, the excess of oxidized silver will re-enter the metal. But under conditions of rapid cupellation and rapid removal of litharge from the metal this condition of supersaturation may not be relieved. Hence, if the silver is actually subject to oxidation to any considerable extent, the litharge produced may contain much more dissolved silver than corresponds to equilibrium conditions. It would appear that in the ordinary laboratory cupellation for determinative purposes, where oxidation is comparatively slow and the litharge is formed as an exceedingly thin film over the surface of the alloy, the conditions would be quite favorable to the attainment of equilibrium between the litharge and the metal. While in furnace cupellation on a large scale where rapid oxidation with forced draft is the rule, the conditions are not so favorable to the attainment of the equilibrium conditions that correspond to the temperature at which the operation is conducted.

Much more experimental work is necessary before the physical chemistry of cupellation can be thoroughly understood. In this paper an attempt has been made, by extending the data secured from experiments with litharge-containing slags, to provide a little information, which appears to be reasonably accurate so far as it goes. That it does not go far enough to settle all of the questions involved is quite evident. But it appears that further work should involve experiments with pure litharge rather than with more or less concentrated litharge slags, and on this account work with the slags has been discontinued. In this connection it may be well to note that the principal difficulty encountered in attempts to study pure litharge lies in securing a proper container for the molten material. Dilution and reduction of the litharge have to be avoided, and molten litharge is almost as fluid as water. Consequently, if the properties of pure litharge are to be studied, the container must be chemically inert to the action of the molten material at high temperatures, and it must be relatively dense and non-porous.

It is because of the difficulties encountered in pro-

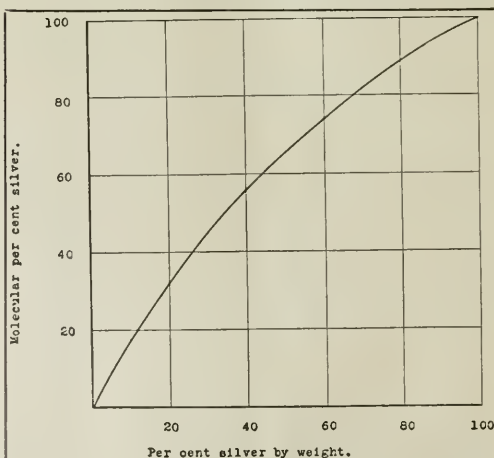


FIG. 6—WEIGHT PERCENTAGES AND MOLECULAR PERCENTAGES OF SILVER IN SILVER-LEAD ALLOYS

curing such an ideal container that the experiments have not been carried further in this direction. It is on this account also that the temptation to extrapolate the results of the slag experiments to the point where the properties of pure litharge are indicated has proved irresistible. The only straw in sight has been grasped; whether the results thereby secured will be shown by actual experiment to be good or otherwise remains to be seen.

Summary

The results of the experimental work recorded above may be summarized as follows:

1. Slags consisting of PbO , Na_2O , SiO_2 , and B_2O_3 retain silver in the presence of metallic lead, a true state of equilibrium between the metal and the slag being attainable under each set of conditions.

2. The total amount of silver retained by the slag is proportional to the weight of the slag. Hence, under definite conditions a definite concentration of silver in the slag is required to produce equilibrium.

3. The concentration of silver in the slag increases with increasing temperature, other conditions being constant. The rate of increase of the silver concentration is somewhat greater than the rate of temperature increase. See Fig. 4.

4. At constant temperature the concentration of silver in the slag varies directly with its concentration in the alloy, with which the slag is in contact.

5. For small concentrations of silver in the metal its concentration in the slag is proportional to its weight percentage in the alloy. With richer silver-lead alloys the silver concentration in the slag is found to be proportional to the molecular percentage of silver in the metal.

6. Litharge is found to be the most active of the slag-forming constituents in point of ability to dissolve and retain silver.

7. Other conditions being constant, the amount of silver retained by the slag is directly proportional to the molecular concentration of litharge in the slag, and is independent of the silicate degree or oxygen ratio of the slag.

8. An extension of the data secured from experiments with the slags yields provisional information in regard to the ability of pure litharge to dissolve and retain silver in the presence of metallic lead.

9. The results are inconclusive in regard to the condition or state in which silver is held in solution by litharge. While in all cases studied the resulting concentration of silver in the slag was found to be what might be expected if the litharge actually dissolves a portion of the alloy with which it is in contact, this fact in no way precludes the possibility of the silver being oxidized to a greater or less extent.

Note.—In the first part of this article published in the issue of June 1, on page 640 in the second column the paragraph beginning "All experiments performed, etc.," is misplaced. It should appear immediately before the paragraph on page 641 in the second column that begins "The average ratios, etc."

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The Kahlfeisch Chemical Corporation will build a new chemical plant at Chattanooga, Tenn., to cost about \$75,000.

The West Virginia Pulp & Paper Company at Mechanicville, N. Y., is installing additional capacity in connection with its alcohol plant. A large Swenson quadruple effect evaporator is being completed for this plant at Chicago and it is expected that this will be erected in a very short while.

Wood Waste and Other Pulpwoods Used in 1914 by United States Mills

BY HENRY E. SURFACE

Engineer in Forest Products, Forest Products Laboratory.

In the latter part of the year 1915, the Forest Products Laboratory was in need of immediate current data in connection with a study of the progress being made in the utilization of wood waste as pulpwood, and since no recent statistics were available from other sources, a questionnaire in this regard was sent out to the various consuming establishments. A summary of the statistics obtained, together with a brief discussion of an incidental consideration brought out by the apparently decreased consumption and the high price being paid for pulpwood by many of the mills is given below as of public interest, although the concerns so kindly co-operating in the study have already received certain advance information.

The 1914 figures of pulpwood consumption given herein must be considered more in the nature of estimates than as formal statistics. The latest official data on the wood and wood waste used in the United States for the production of paper pulp, that are at present available to the public, are those covering the year 1911 as published by the Bureau of Census, U. S. Department of Commerce, in its circular entitled "Forest Products No. 1; Pulpwood Consumption: 1911." Similar official statistics had been prepared in co-operation with the Forest Service, U. S. Department of Agriculture each year since 1905 but they were discontinued in 1911, and under the existing plan the only sources of such information will be the decennial and quinquennial censuses. The most recent of these, namely, the "Census of Manufactures: 1914" covered the pulpwoods used in that year, but the rather comprehensive data collected will probably not be in shape for publication until late in 1916. When these figures become available it will be interesting to observe in comparison those given below, since both cover the calendar year 1914. In doing so, it should be remembered that this present inquiry was made for a special purpose entirely foreign to the usual census needs. It did not cover so great a field, and absolute statistical accuracy was not essential since merely an indication as to the general trends of certain features was desired. The fact that all mills were not covered by the reporting concerns, while a matter to be regretted, was not one to void the success of the inquiry.

The establishments to which schedules were sent in this inquiry were those equipped for the manufacture of groundwood and chemical fiber in the United States as listed in "Post's Paper Mill Directory: 1915," which presumably covers the 1914 equipment. The individual schedules were summarized in various ways and those items of most interest to the public are given in condensed form as follows:

SUMMARY OF PULPWOOD DATA

NOTE.—Amounts are expressed in standard stacked cords of 128 cu. ft. each. The "wood waste" in question, otherwise called "sawmill waste," or "mill waste," consists of slabs, trimmings, edgings, shavings, cores and other similar wastes of sawmills, planing mills, and other wood working establishments. Items 4 and 5 are estimations based on the reasonable assumption that the plants not reported upon must have consumed on the average as much wood in proportion to their capacities as did the reporting concerns (see item 3); the great preponderance of the latter (90:10) minimizes any inaccuracy in this regard. So far as could be learned from outside sources there was no marked variation in the proportion of idle and operating plants among those not reporting as compared to the others.

1. Total number of pulp mills in U. S. A., 250; proportion of same covered by reporting concerns, 90.0 per cent.

2. Total potential wood-consuming capacity of all pulp mills, 6,499,760 cords per annum; proportion of

such potential capacity covered by reporting concerns, 82.1 per cent.

3. Ratio of actual pulpwood consumed to potential capacity, for reporting concerns, 66.0 per cent; ratio of wood waste used as pulpwood to total pulpwood, 7.7 per cent.

4. Estimate of total pulpwood (including wood waste) consumed by all mills whether reporting or not, about 4,290,000 cords; estimated cost, about \$36,800,000.

5. Estimate of total wood waste used as pulpwood by all mills whether reporting or not, about 330,000 cords; estimated cost, about \$1,400,000.

6. Distribution of wood waste used as pulpwood by reporting concerns, according to process of manufacture; mechanical, 3 per cent; sulphite, 76 per cent; sulphate, 13 per cent; soda, 8 per cent.

7. Average costs per cord delivered at mills of reporting concerns; for pulpwood of all kinds \$8.58; for wood waste, only, \$4.25.

8. Classified costs of pulpwood of all kinds and of specified kinds, delivered at mills is given in Table I.

TABLE I

Cost per Cord	NUMBER OF REPORTING CONCERNS				
	Pulpwood*, All Kinds	Rough Wood	Peeled Wood	Rosset Wood	Wood Waste
\$ 0-80.99	1	0	0	0	3
1.00-1.99	0	0	0	0	0
2.00-2.99	3	1	0	0	3
3.00-3.99	1	2	0	0	6
4.00-4.99	7	4	1	0	3
5.00-5.99	13	4	0	0	6
6.00-6.99	14	12	5	0	1
7.00-7.99	16	12	7	0	2
8.00-8.99	22	16	9	1	1
9.00-9.99	28	25	7	3	3
10.00-10.99	28	10	24	2	0
11.00-11.99	14	5	17	1	1
12.00-12.99	11	1	6	9	0
13.00-13.99	7	0	2	14	1
14.00-14.99	6	0	0	13	0
15.00-15.99	4	0	0	4	0

*For example, 7 concerns paid between \$4 and \$5 for the average cord of wood used by each in 1914, regardless of form whether rough, peeled, rosset or waste.

EXPLANATION OF ITEMS

Items 1, 6, 7 and 8 were obtained solely from the schedules.

The potential wood consuming capacity as given under item 2 is a hypothetical value signifying the greatest amounts of wood that all the pulp mills of the United States could use in a year if they were to operate at full rated capacity 360 days for mechanical mills and 310 for chemical mills. This value, which was needed for making the estimates in items 4 and 5, was obtained from the pulp producing capacities of the mills as recorded in Post's Paper Mill Directory, 1915, assuming one ton of mechanical pulp equivalent to one cord of wood, and one ton of chemical pulp equivalent to two cords of wood. Obtained in this way the value itself may or may not be anywhere near correct; for the purpose at hand, it really matters little how far off it may be. The important thing is that it will be as nearly correct for all of the mills as the similarly obtained value (3,522,108 cds.) is for the reporting concerns, and the resultant ratio (82.1 per cent) between the two values must be quite accurate in consequence.

The data under item 3, obtained jointly from the schedules and from item 2, show that the reporting pulp mills operated to practically two-thirds (66.0 per cent) of their "potential capacity" during 1914, while of the total pulpwood reported 7.7 per cent was wood waste. The estimates of amounts of pulpwood and of wood waste under items 4 and 5 assume that these same ratios hold good for all of the American pulp mills in-

cluding the small number (10 per cent) or small capacity (17.9 per cent) not actually reported upon. Even if the ratios for the non-reporting mills alone were as much as 30 per cent off from the average of the reporting concerns, it would put the estimates in error by only about 5 per cent and, moreover, it would be scarcely believable that every last one of the twenty-five non-reporting mills were operated under such phenomenally good (or phenomenally poor) conditions that their individual variations from the average would all be in the same direction to the extent of 30 per cent or any other large proportion. The natural tendency would be for these individual variations to practically offset each other. Likewise, the estimated costs under items 4 and 5 are based on assumptions that the average prices per cord for the reporting concerns (item 7) would very nearly hold good for all of the mills, but they, of course, are purely rough approximations.

It should be noted that the percentage distribution of pulpwood by processes of manufacture, as given under item 6 apply only to the wood waste and not to the great bulk of total pulpwood.

The average costs under item 7 were obtained by dividing the total costs of all wood reported upon by the total number of cords reported with cost figures accompanying.

In item 8 the number of concerns noted under the several kinds of pulpwoods reported does not signify number of establishments or mills. This is of importance since some of the reporting concerns recorded a single cost figure to apply to two or more mills, under the same local management, for which no distinction was made in figuring wood costs.

In view of the above explanation as to just how the several figures were obtained there is no apparent objection to making them public. The "estimates" in particular are given for whatever they may be worth in the opinion of those finding use for them and the only assurance which can be given as to their ultimate reliability is that they are as accurate as the mill reports and the statistical laws of averages will afford under carefully checked compilations.

Assuming the figures above to be measurably correct, it is interesting to compare them with similar figures for previous years and thus get an idea as to where the wood pulp industry stands to-day. Table II will serve this purpose:

TABLE II—CONSUMPTION OF PULPWOOD BY UNITED STATES MILLS

Year	Pulpwood, All Kinds* Cords	Wood Waste Only Cords	Authority
1914	4,290,000	330,000	Unofficial estimates
1913	.....	.....	No data available
1912	.....	.....	No data available
1911	4,328,052	280,534	Forest Service and Bureau of Census
1910	4,094,306	262,637	Forest Service and Bureau of Census
1909	4,001,697	248,977	Forest Service and Bureau of Census
1908	3,346,953	(a)	Forest Service and Bureau of Census
1907	3,962,660	(a)	Forest Service and Bureau of Census
1906	3,661,176	(a)	Forest Service and Bureau of Census
1905	3,192,223	(a)	Forest Service (H. M. Hale)
1899	1,986,310	(a)	Bureau of Census

(a) Not reported separately.

*These figures cover both domestic and imported goods.

It is a matter of surprise that the figures of Table II show the American wood pulp industry to have declined since 1911, although it is well recognized in the trade that the United States production of pulp from wood has not been keeping up with the actual domestic consumption of pulp and paper products. Even were the 1914 figures too low by 5 per cent, the industry apparently would not have made the normal gain during the last three years that its previous record warranted.

In seeking reasons why the American industry made little or no progress in 1914, one finds two important factors, aside from the previous large and steadily increasing importations of European pulps, that would have operated either separately or in combination to bring this about. In the first place, 1914 was a year of severe depression for business in general; the next preceding year of severe business depression was in 1908, which is similarly reflected in a decreased wood consumption for that year, as compared with both 1906 and 1907. On the other hand, consideration cannot be given the possibly waning industry of this country without reference to the vigorous growth of the Canadian industry during the last few years, inasmuch as the greater portion of its products (e.g., something like nine-tenths of its news print) is marketed in the United States. While general business depression in 1914 was as pronounced in Canada as in the United States, yet the Canadian wood pulp industry continued its remarkable development. A comparison of the United States record, as above, with that of Canada, as given in the following excerpt from the *Papermill and Wood Pulp News*, Aug. 7, 1915, page 18, is quite enlightening:

"Canadian statistics show that the consumption of pulpwood in Canada increased nearly 10½ per cent in 1914, compared with 1913. Since 1910 the increase has been 104 per cent. The 66 active pulp mills in Canada in 1914 consumed 1,224,376 cords of pulpwood, valued at \$8,089,868, while in addition to this 972,508 cords valued at \$6,680,490, were exported in an unmanufactured state. In 1914, 55.7 per cent of all pulpwood produced in Canada was made into pulp in Canada and 44.3 per cent was exported, chiefly to the United States in the raw or cordwood state. Formerly, only one-third of the pulpwood produced in Canada was made into domestic pulp."

Disregarding all artificial restrictions on the course of trade, it is but the natural outcome that the wood pulp industry should gravitate more and more from the eastern United States to Canada, from a region where pulp wood is becoming scarce and costly to one of more abundant and cheaper timber. In time, the present manufacturing regions, even in Canada, will have to yield likewise to other and newer sources of supply.

While other natural resources and facilities than timber are of importance, it is not necessary to look further than the 1914 figures on American pulp wood costs (item 8 above) to understand how Canada, with an average wood cost of about \$6.50 per cord and with legislation as well as sentiment restricting the exports of pulp wood, has been able to attract the industry, even though the market is on the American side.

Something like one-third of the United States companies are now paying from \$10 to \$16 per cord for their entire supply of wood and, without prospect of relief in sight, realize the outcome of trying to compete with mills more favorably circumstanced. In consequence, a number of American operators have been acquiring Canadian interests, but some, unwilling to forsake purely domestic manufacture, are of the opinion that it might be better to transfer their energies and resources from the wood pulp industry to other lines of endeavor.

Still others, neither willing to move to Canada nor wishing to abandon the industry altogether, may sooner or later find it worth while to shut down their Eastern plants and operate in southeastern Alaska or in the West, where water power is absurdly cheap and eminently suitably pulp timber from the National Forests, at least, can be delivered to desirable mill sites for the next twenty to forty years at prices of about \$2.50 to \$4 per cord, covering all charges, and this without any investment in timberlands, without taxes or fire risks.

It is at least significant that the enormous savings they could affect in wood costs per ton under such con-

ditions would more than offset the higher freight rates they would have to pay to bring finished paper or chemical pulp to their original Atlantic seaboard markets without trying to enter new ones. Even the 1915 marine rate of 40 cents from coast to coast is not particularly discouraging under such considerations.

In consequence of existing conditions and of those to be expected, there are already specific opportunities for Western enterprises that will doubtless excite the curiosity of some of the Eastern operators if not their more serious consideration. Of course, real difficulties in the way of such new developments must be expected, but the risks are growing less each year and close investigation eliminates many of the usual stock objections.

The signs of the times indicate that if the United States is to retain its pre-eminence in wood pulp manufactures it will evidently have to make use of its wonderful Western and Alaskan resources. Even the use of wood waste, as indicated by the above tabulation, while encouraging in the steady progress that has been made, does not at present seem sufficient to warrant the hope that it will be the predominant factor in keeping our industry at home.

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Extraction of Gold and Silver from Matte by Lead*

BY W. MOSTOWITSCH

In practice there are two different processes for the extraction of the noble metals from materials containing gold and silver.

1. Smelting with lead ores or lead-carrying materials in the blast furnace. The resulting base bullion is desilverized and the gold and silver parted.

2. Treatment of mattes and speises with molten lead (Crooke and Davies). The treatment of copper matte with molten lead for the removal of gold and silver is still used in Japan (Bull. A. I. M. E., Nov., 1914, p. 2693).

The results from practice show in general that the gold collects chiefly in the base bullion, the silver dividing itself between base bullion and matte. The percentage extraction of silver is lower, the greater the amount of matte for the same amount of base bullion. This fact is illustrated by table III in an article by M. Ortin (Metall und Erz, 1913, p. 840).

Experimental results are given in an article by S. Blisinski (Chemik Polski, XII, 1912, No. 8). He made a series of synthetic mattes by melting together FeS (Fe = 70.25, S = 25.54 per cent) with Cu₂S (Cu = 78.8, S = 20.98 per cent) in such proportions, that the resulting mattes contained about 25 per cent copper. These mattes were repeatedly remelted with powdered silver and gold. Thirty grams of this material was then melted with lead in a muffle furnace in a graphite crucible. In these tests the quantity of the lead, the temperature, and the duration of the melting were varied. In the resulting product lead, gold, and silver were determined. The first series of experiments were made with mattes A and B of the following analyses:

	Ag	Cu	Fe	S
A.....	7.32	17.10	46.80	25.24
B.....	8.80	17.50	44.95	25.18

Thirty grams each of A and B were melted with 15 to 120 gr. Pb at 1000, 1100 and 1250 deg. C. for from 45 to 90 minutes.

*Translated in abstract from the Journal of the Russian Metallurgical Society, 1914, No. 4, pp. 511 to 532.

The results of these experiments showed that lead extracted 72 to 93.8 per cent of the silver; the percentage extraction increased as the amount of lead increased and it also increased with rising temperature but decreased as the time of heating increased.

Experiments were made with a gold-containing matte of the following composition: Au 1,247, Cu 17.65, Fe 49.90, S 27.77. Thirty grams of matte were melted with 30 to 90 gr. of lead at 1000, 1100, and 1250 deg. for 45, 90 and 135 minutes. According to the analyses the extraction of gold was influenced much less by the amount of lead than was the extraction of silver. When the lead varied in amount from one to three times the weight of

the matte, the gold extraction varied between 95.2 and 99.3 per cent. The temperature and time of heating had very little effect.

From these experiments it appears that a contact between the lead and gold is sufficient to obtain an extraction of 93.3 to 99.3 per cent, still under the same conditions the solubility of the gold in lead is higher than the silver. If we assume the ratio of the weights of Pb to matte to be n , and the per cent extraction of the silver = P_{ag} , that of the gold = P_{au} , we have:

	$n=1$	$n=2$	$n=3$
At 1000 deg. C. and 45 min. heating P_{ag}	83.47	91.35	90.62
P_{au}	99.06	98.77	98.87
At 1100 deg. C. and 45 min. heating P_{ag}	82.92	90.85	93.58
P_{au}	96.87	99.33	99.14

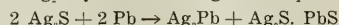
The solubility of the gold in lead is so great that the change from $n=1$ to $n=3$, has not much effect on the extraction. It is interesting to note what the minimum amount of lead is, which will extract all the gold. For copper we have the researches of Gibb (H. O. Hofman, Metallurgy of Copper, p. 295).

Experiments were made in our laboratory as follows: Twenty grains of a gold-carrying matte were melted in a cryptol furnace in Tammann carbon tubes at 1050 deg. C. with different amounts of lead. Stirring was done with a carbon rod. The copper matte contained Cu 36.92 per cent, Fe 36.98, S 24.40, Au 0.00335 per cent, Ag 0.0354 per cent. The results are given in Table I.

The following conclusions may be drawn:

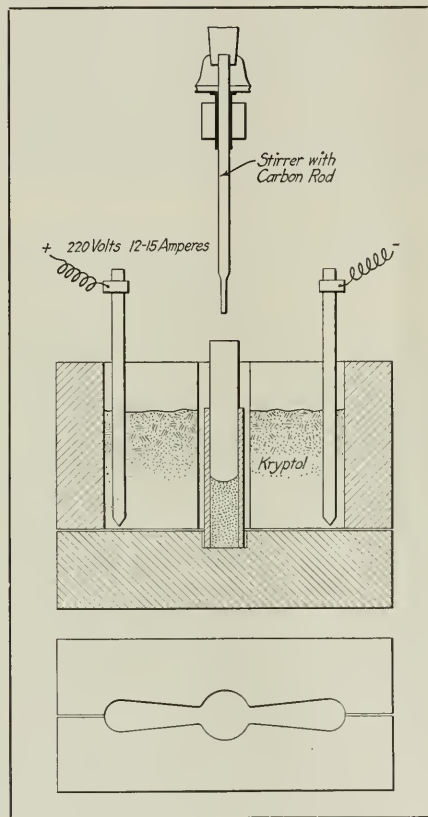
1. The percentage extraction of the gold and silver is proportional to the amount of lead added.
2. With an amount of lead equal to 80 per cent of the weight of the matte practically all the gold is extracted.
3. The extraction of the silver reaches only 72 per cent with equal amounts of lead and matte.

The form in which gold and silver exist in mattes is not yet fully established. It may be assumed that the silver is combined as Ag_2S , while it is possible and quite probable that the gold occurs uncombined, or alloyed with the sulphides or metals in the matte. Evidence in favor of the assumption as to silver, is found in the difficulty of the extraction of the silver. The decomposition of Ag_2S by lead according to the equation



proceeds to the formation of an alloy $Ag_2S. PbS$, and as a result the extraction of the silver through a single treatment with lead cannot be accomplished.

Experiments were made to clear up this question. The experiments were also intended to show whether lead treatment of the matte could be used as a method for the analytical determination of the gold in the matte since the known analytical methods for this purpose are too



EXPERIMENTAL ELECTRIC FURNACE

TABLE I

Experiment No.	Matte, Gr.	Lead, Gr.	Au in Matte, Mgr.	Ag in Matte, Mgr.	Matte + Lead After Melting, Gr.	Base Bulion, Gr.	AU AND AG IN BASE BULLION		EXTRACTION IN PER CENT		REMAINING IN MATTE AFTER EXTRACTION			
							Au, Mgr.	Ag, Mgr.	Au	Ag	Au, Mgr.	Ag, Mgr.	Au, per Cent	Ag, per Cent
1	20	4	0.67	7.08	23.5	1.8	0.35	1.95	52.24	27.54	0.32	4.97	48.8	70.26
2	20	6	0.67	7.08	25.3	3.4	0.44	2.46	65.67	34.75	.....	.....	.....	.....
3	20	8	0.67	7.08	27.3	4.6	0.50	3.00	74.63	42.37	.....	.....	.....	.....
4	20	8	0.67	7.08	27.6	4.9	0.50	3.10	74.63	43.78	.....	.....	.....	.....
5	20	10	0.67	7.08	29.7	7.1	0.57	3.58	85.1	50.57	.....	.....	.....	.....
6	20	10	0.67	7.08	29.3	7.0	0.57	3.63	85.1	51.27	.....	.....	.....	.....
7	20	12	0.67	7.08	31.3	9.6	0.65	3.95	97.01	55.78	.....	.....	.....	.....
8	20	12	0.67	7.08	31.2	9.3	0.65	3.95	97.01	55.79	0.015	3.28	2.24	46.38
9	20	14	0.67	7.08	33.4	10.5	0.66	4.04	98.50	58.62	.....	.....	.....	.....
10	20	14	0.67	7.08	33.2	10.8	0.66	4.04	98.50	58.62	0.01	2.90	1.50	42.23
11	20	16	0.67	7.08	35.2	12.4	0.67	4.18	100	59.04	.....	.....	.....	.....
12	20	18	0.67	7.08	37.2	15.3	0.67	4.53	100	63.98	.....	.....	.....	.....
13	20	20	0.67	7.08	38.6	16.8	0.67	5.08	100	71.75	.....	2.0	.....	28.25

long, too complicated and too costly. Six mattes of the composition shown in Table II were tested.

TABLE II

	IN PER CENT					MGR. IN 10 GR.	
	Cu	Pb	Fe	Zn	S	Ag	Au
Matte I.	28.12	0.72	40.15	1.51	24.79	2.06	0.29
Matte II.	11.90	0.86	49.85	....	24.95	17.52	4.73
Matte III.	19.71	4.19	42.58	....	25.85	22.13	1.83
Matte IV.	41.23	7.15	24.32	....	22.72	49.44	9.52
Matte V.	66.88	8.68	2.61	....	18.40	5.262	0.44
Matte VI.	46.42	19.65	0.23	1.25	17.60	1300	22.8

Mattes I to V are crude and concentrated mattes from copper and copper-lead smelting at Ural smelters.

Matte VI was obtained from gold-zinc precipitates from a gold mine.

Experiments were made with 10 to 15 grams of matte heated in carbon tubes in a cryptol furnace at 950-1000 deg. C., whereupon 10 to 25 grams of lead were added. To accelerate the extraction, the melt was stirred with a carbon rod. At all temperatures the melt forms two layers, namely lead and matte. The contents were then placed in a crucible which was heated to full redness in an electric furnace. At one and the same temperature the extraction of the noble metals depended on the amount of lead and duration and intensity of stirring. The effects of these factors were tested with the results given in Table III.

The experiments were made with mattes of different origin, character, and gold and silver content. Nevertheless, the extraction of the gold was about 100 per cent, that of the silver 64.4 to 96 per cent. From forty-

four tests it is seen that the extraction of the gold is independent of the ratio of the weights of lead and matte, and also independent of the duration and intensity of agitation.

For mattes I and II, the ratio of the weights of lead to matte varied between 1 and 2.5.

For mattes III-V, the ratio of the weights of lead to matte varied between 1.5 and 2.5.

For matte VI, the ratio of the weights of the lead to matte varied between 2 and 6.

The duration of agitation varied between 5 and 15 minutes, the intensity of agitation between 300 to 650 rotations per minute and under all these conditions the extraction of the gold was 100 per cent. For silver, the extraction increased with the ratio of lead to matte.

For matte II—n=1.	Extraction=81.2
n=1.5	84.0
n=2.0	92.2
n=2.5	96.0
For matte III—n=1.5	79.0
n=2.5	90.9
For matte IV—n=1.5	83.0
n=2.5	87.0
For matte VI—n=2.5	75.9
n=4	86.1
n=6	90.8

The variation of the time and intensity of agitation had but little effect on the extraction as shown by the following:

Matte IV.	10 min. 500 rotations per min. extraction	42.97
	5 min. 200-300 rotations per min. extraction	40.95

The relation between the percentage extraction of the silver and the copper content of the mattes is evident from Table IV.

TABLE III

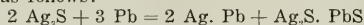
Experiment No.	AGITATION					Base Bullion, Gr.	Cu in Matte, per Cent	IN 10 GR. OF MATTE		IN BASE BULLION		IN 10 GR. MATTE AFTER AGITATION		EXTRACTION			
	Matte No.	Matte, Gr.	Lead Added, Gr.	Time of Heat-ing, Min.	Rotations of Stirrer per Min.			Ag. Mgr.	Au. Mgr.	Ag. Mgr.	Au. Mgr.	Ag. Mgr.	Au. Mgr.	Mean Ag. Mgr.	Mean Au. Mgr.	Ag. per Cent	Au. per Cent
1	II	10	10	10	650	8.8	11.9	17.52	4.73	14.35	4.75	....	....	....	....	....	....
2	II	10	10	10	650	8.1	11.9	17.52	4.73	14.50	4.75	3.6	....	14.23	4.78	81.2	100
3	II	10	10	10	650	8.9	11.9	17.52	4.73	13.85	4.85	....	....	....	....	....	....
4	II	10	20	10	600	18.8	11.9	17.52	4.73	16.25	....	....	....	....	....	....	....
5	II	10	20	10	600	19.0	11.9	17.52	4.73	16.05	4.75	2.1	....	16.15	4.75	92.2	100
6	II	10	25	10	600	23.7	11.9	17.52	4.73	17.12	4.78	....	....	....	....	....	....
7	II	10	25	15	600	23.9	11.9	17.52	4.73	16.32	4.78	1.5	....	16.82	4.78	96	100
8	II	10	15	5	310	14.0	11.9	17.52	4.73	14.60	4.70	....	....	....	....	....	....
9	II	10	15	5	310	13.5	11.9	17.52	4.73	14.85	4.80	....	....	14.72	4.75	84	100
10	III	10	25	10	340	23.8	19.71	22.13	1.83	19.95	1.85	....	....	20.10	1.83	90.9	100
11	III	10	25	10	340	24.4	19.71	22.13	1.83	20.55	1.85	....	....	....	....	....	....
12	III	10	25	10	340	23.9	19.71	22.13	1.83	19.70	1.80	....	....	....	....	....	....
13	III	10	25	10	340	24.3	19.71	22.13	1.83	20.20	1.80	....	....	....	....	....	....
14	III	10	15	5	310	14.0	19.71	22.13	1.83	17.15	1.85	....	....	....	....	....	....
15	III	10	15	5	310	14.0	19.71	22.13	1.83	17.30	1.85	....	....	17.47	1.85	79	100
16	III	10	15	5	310	14.0	19.71	22.13	1.83	17.95	1.85	....	....	....	....	....	....
17	IV	10	25	15	500	24.7	41.23	49.44	9.52	43.9	9.40	....	....	42.97	9.33	87	98
18	IV	10	25	15	500	24.8	41.23	49.44	9.52	42.9	9.30	....	....	....	....	....	....
19	IV	10	25	15	500	24.7	41.23	49.44	9.52	42.8	9.30	....	....	....	....	....	....
20	IV	10	15	5	300	14.7	41.23	49.44	9.52	41.25	9.70	....	....	....	....	....	....
21	IV	10	15	5	300	14.2	41.23	49.44	9.52	40.85	9.55	....	....	40.95	9.62	83	100
22	IV	10	15	5	300	14.5	41.23	49.44	9.52	40.75	9.60	....	....	....	....	....	....
23	V	10	25	15	370	25.6	66.88	52.65	0.44	41.58	0.52	....	....	....	....	....	....
24	V	10	25	15	310	25.5	66.88	52.65	0.44	41.60	0.50	....	....	41.15	0.50	78.1	100
25	V	10	25	10	310	25.0	66.88	52.65	0.44	40.7	0.50	....	....	....	....	....	....
26	V	10	25	10	310	25.2	66.88	52.65	0.44	40.7	0.50	....	....	....	....	....	....
27	V	10	15	5	300	15.5	66.88	52.65	0.44	33.80	0.43	....	....	33.93	0.43	64.4	100
28	V	10	15	5	300	15.7	66.88	52.65	0.44	33.82	0.43	....	....	....	....	....	....
29	V	10	15	5	300	15.1	66.88	52.65	0.44	34.17	0.43	....	....	....	....	....	....
30	I	10	25	10	340	23.8	28.12	2.06	0.29	2.6	0.26	....	....	2.4	0.28	100	100
31	I	10	25	10	340	23.6	28.12	2.06	0.29	2.3	0.26	....	....	....	....	....	....
32	I	10	25	10	340	24.0	28.12	2.06	0.29	2.7	0.30	....	....	....	....	....	....
33	I	15	15	5	300	13.0	28.12	3.09	0.45	3.45	0.50	....	....	....	....	....	....
34	I	15	15	5	300	13.0	28.12	3.09	0.45	3.45	0.47	....	....	3.34	0.49	100	100
35	I	15	15	5	300	13.0	28.12	3.09	0.45	3.13	0.50	....	....	....	....	....	....
36	VI	5	10	5	300	....	46.42	650	11.4	502.05	11.55	....	....	....	....	....	....
37	VI	5	10	5	300	....	46.42	668	11.62	510.85	11.55	163.5	....	506.92	11.55	79.90	99.4
38	VI	5	10	5	300	....	46.42	668	11.62	507.85	11.55	....	....	....	....	....	....
39	VI	5	20	5	300	....	46.42	668	11.62	575.8	11.60	....	....	....	....	....	....
40	VI	5	20	5	300	....	46.42	668	11.62	581.5	11.90	92.5	....	575.4	11.66	86.1	100
41	VI	5	20	5	300	....	46.42	668	11.62	568.9	11.50	....	....	....	....	....	....
42	VI	5	30	5	300	....	46.42	668	11.62	612.5	11.50	....	....	....	....	....	....
43	VI	5	30	5	300	....	46.42	668	11.62	606.51	11.60	67.0	....	606.4	11.53	90.8	99.4
44	VI	5	30	5	300	....	46.42	668	11.62	597.1	11.50	....	....	....	....	....	....

TABLE IV

n = Lead to Matte	PER CENT CU IN MATTE				
	11.90	19.71	41.23	46.42	66.88
	EXTRACTION PER CENT				
1.5	84	79	83	75.9	64.4
2	92.2	90.9	87	75.9	78.1
2.5	96				

For the same weight ratio of lead to matte the extraction of the silver decreases with increasing copper content.

Such an easy and complete extraction of the gold from the mattes makes it probable that the gold exists in matte in the free state, as a mechanical mixture. This view is also supported by the fact that gold occurs in a similar free form in most natural sulphides whereby the extraction by cyanide solution is explained. The silver occurs in matte chiefly as Ag_2S . Accordingly the extraction of the silver depends on the breaking up of this compound as follows:



This reaction proceeds, as is known, to the formation of a new matte system. In our case $\text{Ag}_2\text{S} \cdot \text{PbS}$ is formed and when the concentration of the silver in both phases—matte and base bullion—reaches a certain amount, the action of the lead on the newly formed matte ceases and an equilibrium is established between both products.

The lowering of the silver extraction with increasing copper content in copper mattes shows that the copper component of the matte (Cu_2S) binds the silver and on that account the value of the final concentration of the silver in the matte is raised. The lead then loses its action on the Ag_2S . According to the phase diagrams of Friedrich (Metallurgie, IV, 1907, p. 171) it can be seen that out of several sulphides which occur in matte, Cu_2S and Ag_2S form mixed crystals. This indicates that the two sulphides have a large mutual solubility, and this explains the decreasing silver extraction from copper matte, as the copper content increases.

The complete extraction of gold from matte by agitation of the melt with lead, together with the simplicity and ease of operation of the process, indicates the possibility and desirability of the application of this process to quantitative determinations of gold in mattes. This method requires only 2 or $2\frac{1}{2}$ hours, divided as follows: Agitation, 10 minutes; slagging of the base bullion once or twice, $1\frac{1}{2}$ hours; cupellation, etc., 1 hour. A very small amount of reagents is required and the manipulation is simple.

Tomsik, Russia.

Many Industries Represented in Exhibit of Waterworks Appliances.—An exhibition of waterworks appliances was held in the ballroom of the Hotel Astor, New York, in conjunction with the annual Waterworks Convention held June 5 to 9. Among the companies represented were the following: Eimer and Amend, New York (chemicals, laboratory supplies, water stills, etc.); U. S. Cast Iron Pipe & Foundry Co., Burlington, N. J. (cast iron pipe); Bristol Company, Waterbury, Conn. (recording pressure, temperature, and other gages); Worthington Pump & Machinery Co., New York (pumps and all kinds of machinery); Mogul Company, New York (acid-resisting coating for pipes, tanks, etc.); American Bitumastic Enamels Co., New York (non-corrosive enamels); Lead Lined Iron Pipe Co., Wakefield, Mass. (lead-lined iron pipe); Electro Bleaching Gas Co., New York (chlorine).

Flotation Versus Cyanidation

BY JACKSON A. PEARCE

As a factor in ore dressing, flotation is occupying a prominent place and may as well be considered a fixture. Results on lead, copper, and zinc ores are especially gratifying the world over. With these ores the process is additional rather than substitutional. In some instances, jigs, vanners and buddles have been eliminated from the flow-sheet, but as a distinct substitutional process it has found but limited application. In some mills it is true it has substituted cyanidation in the treatment of certain gold and silver-bearing pyritic ores, yet it has not met with the same general success as in its application to lead, copper and zinc ores.

At the Argo mill, Idaho Springs, Colo., some interesting parallel tests have been carried out to show the relative merits of flotation and cyanidation on these pyritic ores. Since November, 1913, I have been treating at this mill a large variety of sulphide ores by concentration and cyanidation. The extraction of the gold has been satisfactory—from 88 per cent to 98 per cent. The extraction of the silver has been less satisfactory—from 50 per cent to 65 per cent. As the mill is supplied exclusively by custom ore, there is an evident limit to the amount of silver an ore may carry and leave a profit to the mill, and with our schedule that limit is not very high.

At the time the tidal wave of flotation flooded this part of the United States we were engulfed to the extent of making numerous and extensive laboratory tests. These tests were satisfactory. However, the success attending the cyanidation of these ores coupled with a later discontinuance of some of the flotation machines installed nearby, mollified our enthusiasm and held flotation in abeyance. It was only when much of the custom ore showed a continued increase in silver that serious attention was paid to flotation.

Difficulties of Operation

To accommodate these ores a flotation unit was installed, giving us two distinct flow-sheets in the mill. The installation of the flotation machine was a simple matter, much simpler than the successful operation of it. Preliminary tests on the silver ore gave an extraction ranging from 87 per cent to 90 per cent, and as much, or nearly as much, was expected in operation. For the first two weeks the new system was a very discouraging affair. It is impossible to state just what the extraction was during this period, for the assays of the discharge averaged slightly higher than those of the feed, erratic sampling accounting for the discrepancy. One thing certain is that on an ore concentrating 4 into 1, not over 1000 lb. of concentrates was produced by flotation during this period. This concentrate was largely lead and zinc, with some copper and pyrite, and an abundance of silica.

Then followed a distressing period of more than two months of alteration and variation. Ore was coming in at a rate sufficient to keep the entire mill in operation. The extraction on the tables was 50 per cent, on the flotation machine nil. To adjust the system to yield a reasonable extraction and at the same time to keep from under the ore, imposed a feverish condition upon us. To begin with, those changes were made that seemed logical to us. Those failing, we resorted to guess work.

"An oil for every ore" was a slogan that consumed a large amount of valuable time. Having tried all the

¹See description of cyanide practice, MET. & CHEM. ENG., July, 1915, vol. XIII, p. 421.

oils from which good results were obtained in the preliminary tests with negative results, we assayed those oils and combinations reported to have given good extraction on these and similar ores. Improvement was not noticeable. Acting on the advice of a reputable flotation metallurgist we studied the effect of the sequence of oils. The sequence of oils, in his personal experience, had made the difference between success and failure. We followed one oil with another throughout the entire plant, then reversed the order. We added oil at every stage of the process from the battery bin to the tail race. The desired results were not forthcoming. Of the oils used, mention may be made of Nos. 75, 350, 400 and 750 of the Pensacola Tar & Turpentine Company, a few pine oils of local brand, refined turpentine, coal tar cresote, coal tar, coal oil, gasoline, asphalt, engine oil, fuel oil and some crude oils.

In desperation we assaulted the machine to satisfy the most trivial suggestions, such as to taking out the baffles, to increasing the submergence, to decreasing the flow, to putting the baffles back, to adding air from an external source. We varied the speed of the agitators from almost nothing up to the overload rate of the motor, giving us a peripheral speed greatly in excess of that generally deemed sufficient. We decreased the size of the agitation cells, and increased the length of the impellers. In short, the only changes we did not make were those that did not occur to us.

Various Theories Considered

Then we attacked the problem from the standpoint of modern theories of flotation, whether generally accepted or not. Durell's theory of occluded gas, and those two closely related theories, the one of interfacial tension, the other of electrostatics, advocates of each of which are to be found among the ablest men in the field of flotation. We put all tangible parts of these theories to the test, going to the absurd extreme of trying to induce electrification from without.

We made an examination of the electrolyte, thinking it at fault, perhaps containing some vitiating soluble constituent of the ore. Or perhaps it lacked certain solutes necessary to the proper electrostatic distribution. Although copper and ferrous iron were found in solution, they seemed in negligible quantities. Mr. Robert J. Anderson¹ points out that the salts of these two metals are harmful to the successful flotation of certain ores. Nevertheless, out of curiosity and because the system seemed to be following no established precedent, we increased the amounts of both salts—an increase could do no harm. We tried ferric salts and table salt, oxidizing agents and reducing agents. Yes, we tried acids, both organic and inorganic. Somehow we succeeded in "diminishing the contractile force in the elastic membrane constituting the film of the bubble," yes, indeed. We had oceans of froth but no pyrite. With an acid electrolyte this voluminous froth carried a superabundance of silica.

Following Durell's line of reasoning, all that is necessary to rid the froth of silica is to increase the osmotic pressure just sufficiently to expel the occluded gas of the silica, yet not sufficiently to expel all the occluded gas of the metallic sulphides. This is done by increasing the ions of the electrolyte, i.e., by the addition of some easily dissociated solute, say sulphuric acid. Accordingly, we added more sulphuric acid, starting with $\frac{1}{2}$ lb. per ton and increasing gradually to 20 lb. per ton. This did not succeed.

Now if we view the conditions in the light of the electrostatic theory we might suspect in so far as the attraction is concerned that the silica and the films

were oppositely charged. In an acid solution this should not be the case, since both oil and air are supposed to be negatively charged at all times, and colloidal silica negatively charged in an acid solution. However, as colloidal silica reverses its polarity with respect to hydrogen and hydroxyl ions, and as no harm would result in reversing the polarity of the silica, we changed from acid to alkaline solution. This made a marked difference in the character of the froth, but an improvement in extraction was not noticeable.

Vagaries of the Process

These theories undoubtedly are of great assistance to the well posted and experienced, but to the uninitiated such as we are they were conducive to no better work than would have been a germ theory of flotation.

We then turned our attention to consistency, trying every step from clear water to mud. And temperature was given a wide range. Told that the machine was overloaded, we reduced the feed gradually to 1/40 its rated capacity.

Such unscientific hit-or-miss tactics ordinarily would visit the contempt of the metallurgical fraternity upon an operation. But such is the obscure and undeveloped state of the theory of flotation, and such the secrecy obtaining until recently as to working details, that only the few are able to examine an ore and prescribe a method of treatment with assurance. The history of flotation is a series of records of variations of conditions and alterations of plants extending over months, and even years.

Distinguished flotation metallurgists whom we consulted were not able to point with conviction to the critical defects in the system. All the many suggestions, and they were thankfully received, were carried out to the letter, yet were they barren of results.

Eventually flotation succeeds, and success is ascribed to certain details of operation. Yet these same details, so essential in one plant, seem of no consequence in another. Compare, as for instance, this plant with the one the success of which depended upon the sequence of oils. These two plants were built by the same engineer, from the same blueprint, of the same size, operating at the same speed, on the same ore, with the same oils, same consistency, same temperature, and as nearly same conditions throughout as possibly could be obtained. In one plant careful and repeated tests seemed to show beyond any question that the sequence of oils was of vital importance, yet in this plant it hadn't the slightest influence. Flotation is successful, but the reasons therefor are not manifest. Flotation in practice is yet far in advance of flotation in theory. With all due respect to the brilliant work now being done along this line, the question still is, "Why is flotation?"

Steady Improvement in Results

In the meantime the extraction was slowly improving. The lead and zinc minerals seemed to respond nicely from the beginning. The gold-bearing pyrite and the silver minerals were obstinate to the last. The extraction by periods showed 50 per cent (due to tables only), 63.3 per cent, 82 per cent and 92 per cent. However difficult it was to attain this last extraction, it was not difficult to maintain.

During this trying period of several months the mill crew, especially the master mechanic, showed the keenest of interest, and to their patience and perseverance is largely due the ultimate success of the undertaking.

Having maintained an extraction of better than 90 per cent by flotation of an ore yielding only 70 per cent by cyanidation, another problem presented itself. As stated before, we were cyaniding successfully some ores

¹This Journal, Feb. 1, 1916.

high in gold but low in silver, and flotation was added merely to take care of the high-silver ores. Now, to maintain two systems in one mill may be cheaper than to maintain the two systems in two mills, but it is far from being less expensive than one system in one mill. From an economic standpoint we could sacrifice some extraction in one system by combining the two, or rather by eliminating one. This sacrifice in extraction depends on the difference in cost of operation and on the grade of the ore. The increased cost of maintaining both cyanidation and flotation, together with the encouraging results by flotation, led to a trial by flotation of those ores heretofore treated by cyanidation. The flotation of gold ore, free-milling to a large extent, has not been conspicuous for its success, and considerable doubt was entertained as to the outcome of the test. It is true that preliminary tests gave surprisingly good results. But many obstacles still lie in the path of the flotation metallurgist, and we had not the same confidence in laboratory tests by flotation as we had, for example, in cyanide tests. However, we had a good working margin.

Competitive Test by Cyanidation and Flotation

For this test, to continue seven days if the flotation results were at all encouraging, 60 tons of ore daily was divided between cyanidation and flotation, the rest of the mill being hung up. As to flotation, the first day's run exceeded our expectations. The second day's run exceeded cyanidation. The following five days' run, extraction alone considered, was one of the prettiest contests it has been my pleasure to witness. The variation in daily extraction did not exceed 2 per cent, with a seven days' average of 96.2 per cent for cyanidation against 96.5 per cent for flotation. This ore runs about 0.80 oz. gold, 1.50 oz. silver, is largely free-milling, and of all the ores in the district is best suited to cyanidation. It carries about 0.20 per cent copper, which is a slight detriment to cyanidation but a valuable asset to flotation.

Cyanidation was temporarily discontinued pending further mill tests by flotation. It is generally accepted and widely advertised that every ore requires an individual oil, "a particular oil for a particular ore," and it was considered advisable to make a more thorough investigation as to the oil requisites of the different ores before abandoning cyanidation altogether.

Cyanidation Abandoned

For a month or so mill tests were made on many of the ores produced within a radius of 15 miles. The extraction during this period averaged 95.01 per cent, as a consequence of which we have abandoned cyanidation. Some idea of the ores treated may be had from the table made from some representative ores.

Character of Ore	Gangue	Oz. Au.	Oz. Ag.	Approximate Ratio of Concentration	Remarks
1 Pyritic	Feldspathic	0.70	1.50	6:1	About 0.2 per cent copper
2 Pyritic	Quartzose	2.06	0.40	2:1	No lead, copper or zinc
3 Pyritic	Quartzose	1.16	2.00	25:1	Free milling
4 Chalcopiritic	Feldspathic	0.44	8.90	4:1	2.0 per cent copper
5 Pyritic	Talcoose	0.62	4.40	15:1	No lead, copper or zinc
6 Pyritic	Feldspathic	0.18	11.60	3½:1	About 0.2 per cent each of lead, copper, zinc

During the test on these ores only one frothing oil was used, No. 400 of the Pensacola Tar & Turpentine Company, with a Wyoming fuel oil as carrier. Since

then, out of curiosity, we have tried the oils that had failed in the earlier tests. These oils included crude wood oils, pine tar oils, crude wood creosote and crude turpentine, furnished by the Pensacola Tar & Turpentine Company and by the United Naval Stores. The extraction was good in all trials, the poorest of which would have been considered highly satisfactory had it been obtained earlier in the work. I have lost much of the esteem I once held for "an oil for every ore," am reconciled to "an oil for any ore," and do not hold in contempt "any oil for any ore." We also reverted to other conditions, such as to consistency, temperature, etc. Some of the best work done was during a cold snap, when we had to break the ice to remove the froth. The consistency seemed to have no further effect than as to the quantity of oil consumed per ton of ore.

As to why we were not successful in the beginning we are not able to say. Now that the oil, consistency, temperature and a few other conditions are out of the way we shall be able to locate at an early date, perhaps, the cause of so much disturbance.

Conditions obtaining at the present time are:

Ore—Pyritic, containing gold and silver and a small amount each of copper, lead and zinc.

Screen size—1 per cent + 60, 34 per cent + 200, 65 per cent — 200.

Consistency—5 or 6 to 1.

Temperature—Mill.

Oil—Wood creosote, 15 per cent; Wyoming fuel, 85 per cent; mixed and fed to the first cell at the rate of 3 lb. per ton of ore.

Acid—None.

Other reagents—None.

Peripheral speed—1200.

Argo Mill,
Idaho Springs, Col.

Synopsis of Recent Chemical and Metallurgical Literature

Chemical Engineering

Rapid-drying Paint.—In the *Bulletin de la Société D'Encouragement*, March-April, 1916, a report is given on a rapid-drying paint (Lory paint) made by the firm of Lorilleux Cie. The report was presented by Mr. ACH. LEVACHE, representing the Comité des Arts chimiques. As many as three coats can be given in one day. The rapid-drying is obtained by using, instead of refined linseed oil, linoline or linseed oil solidified by oxidation, such as obtained in linoleum manufacture. This is dissolved in a small quantity of slightly acid amyl alcohol and then a considerable quantity of turpentine is added. When this solvent evaporates, the paint is completely dry, since the oil has been oxidized in advance.

The paint is sold in cans, already prepared, containing the pigment, such as zinc oxide, the oil and the turpentine. In one test made with the paint, a first coat was put on using three quarts at 9 o'clock, followed by a second coat of three quarts at 12 o'clock. The first coat did not roll under the brush when applying the second coat. A third coat of one quart was given at 2 o'clock. Other tests confirmed the above results. What the lasting qualities are, only time can tell, but in one case walls coated with the paint show no sign of deterioration after five years. The price of the paint in normal times would be a little higher than ordinary zinc paint, but its advantages in quick drying outweigh the extra cost in many cases where quick drying is desirable.

Solubility of Naphthalene in Ammonia.—In *Zeits. für Ang. Chemie*, Feb. 22, 1916, SIEGFRIED HILPERT discusses the solubility of naphthalene in water and liquid ammonia. Lunge in his "Steinkohlenteer" states that naphthalene is insoluble in water, while Dr. Franz Fischer (Bronn, *Verflüssigtes Ammoniak als Lösungsmittel*, page 226) gives the solubility of naphthalene in pure liquid ammonia as being very slight. The experiments described by the author did not confirm these statements as to the solubility of naphthalene.

Experiments were made at 0 deg. and 25 deg. C. Three hundred grams of ammonia water of 5, 10 and 25 per cent strengths were agitated with 2 gr. of naphthalene for 15 hours at 25 deg. C. and then filtered. The determinations at 0 deg. were made in ice for 12 hours. The naphthalene was determined by neutralizing the ammonia with sulphuric acid, the naphthalene separating out, and being forced over with steam. The naphthalene is then dissolved in ether, a known amount of picric acid added, the ether distilled off, and the excess acid titrated with standard caustic. The method takes only about $\frac{1}{2}$ hr.

The results of the solubility tests of naphthalene are given in the following table. The results are given as grams of naphthalene soluble in 1000 gr. of solution:

Per Cent NH_3	Solubility	
	0°	25°
0	0.019	0.030
5	0.030	0.044
10	0.042	0.074
25	0.064	0.162
100	33.	120.

In practice the components are not so pure, consequently the addition of 2 per cent pyridine was tried, which raised the solubility at 0 deg. to 0.082 and at 25 deg. to 0.245. Phenol was also tried and it was found to have little effect. Carbonic acid or hydrogen sulphide when present have a much greater effect, but a quantitative test was not made.

Experiments were made to determine the proportions of naphthalene and ammonia coming over upon distilling an ammoniacal solution. The vapors showed a changing proportion of naphthalene to ammonia, as in the solutions. They are richer in naphthalene the higher the temperature of distillation. On the other hand the proportion is lower than required by the partial pressure of the naphthalene at the distillation temperature. In general it is advisable to keep the temperature of the conducting columns above 30 deg.

Chemical Theory

Transmutation of Chemical Elements.—Some interesting experiments on radioactivity, with a view to inducing it in other substances are described in the *Zeit. für Phys. Chemie*, vol. 90, page 557 (1916), vol. 89, page 151 (1915), and Dec., 1914, by W. P. JORISSEN and J. A. VOLLGRAAF of the University of Leiden, and abstracted in *London Engineering*, May 12, 1916. The authors first tried uranium oxide (UO_2), which was placed in a dish of Jena glass on an anode of platinum, the cathode of their bulb being of aluminium; currents of up to 4 milliamperes were used, the gas pressure in the bulb being below 0.05 mm. There was no visible change apart from a colour change, the grey oxide turning black; the grey colour could be restored by heating the oxide in oxygen, and it is very probable that the UO_2 had given off some oxygen under the cathode-ray bombardment. But the radioactivity of the oxide, as tested by the electroscope, was not changed, and that had been the chief object of the experiment. The investigators then took bismuth. P. Villard had observed in 1900 that bismuth was photographically active after bombard-

ment; he did not state, however, whether there had not been any activity before the bombardment, and Jorissen and Ringer had not been able to confirm his observation in 1907. For the new experiments they placed the powdered bismuth again in a glass dish; the glass broke, however, and the bismuth fused, evaporated, and formed a bismuth mirror on the wall of the bulb. The glass was then replaced by quartz. The treatment did not render the bismuth at all radioactive, nor did the metal act on a photographic plate, as Villard had stated. The chemical analysis by Schoorl showed that the original bismuth had not contained any thallium; traces of calcium and also of potassium and sodium were, however, found in the bismuth mirrors, and these metals were probably due to a contamination by the glass of the bulb. These chemical analyses were supplemented by spectroscopic tests, and then a trace of thallium was discovered in the untreated bismuth; the thallium lines were faint, however, and were not any stronger in the treated metal than in the untreated metal. The presence of these traces of thallium is not surprising. Herapath proved in 1863 that thallium is a frequent companion of bismuth, and this was confirmed by Sir W. Crookes, the discoverer of thallium. The reasons for the search for thallium is that the atomic weight of bismuth is 208 and that of thallium 204; the two atomic weights thus differ by 4, which is the atomic weight of helium. The idea was that the cathode-ray bombardment might expel an α ray (a helium atom) from the bismuth. It may be objected, however, that the treatment only lasted a few periods of four hours or less. Radioactive phenomena, it is known, are not affected by the ordinary changes in temperature, pressure, etc., producible in the laboratory; extraordinary violence might have effects. It might also be mentioned that the atomic weight of bismuth was some years ago supposed to be 208.5, and that some chemists again favor this value, while the international tables give the weight as 208.0.

Copper

Allotropy of Copper.—In the *Journal of the Washington Academy of Sciences*, Dec. 19, 1915, Messrs. G. K. BURGESS and I. N. KELLBERG give the results of some experiments made at the Bureau of Standards on the allotropy of copper. According to the work of Prof. E. Cohen (see this journal, Sept. 1, 1915, p. 536) copper has a transition point between 69.2 deg. C. and 71.7 deg. C. under varying conditions of fineness and previous contact with an electrolyte. The authors made a series of experiments by an electric resistance method, in the range 0 to 100 deg. C. The results were negative, i. e., they failed to find any transition points in this range.

The copper used was in the form of hard drawn wire 0.005 cm. diameter by 35 cm. long, wound, together with a platinum wire of 0.015 cm. diameter, on a mica frame and inclosed in a glass tube. This was immersed in a completely waterjacketed and electrically controlled calorimeter, the temperature of which could be made to vary uniformly between 0 and 95 deg. C.

Three methods of measurement were used, as shown in the illustration.

1. The resistance of the Pt and Cu coils was measured differentially, and simultaneous observations of temperature were taken with a mercury thermometer.

2. Using the same coils, a commutator was inserted which permitted taking alternate readings of Pt resistance, which then served as a thermometer, and of the Pt-Cu resistance difference.

3. The Pt and Cu resistances were measured separately with a common lead and a common battery lead and the times taken to 0.1 second on a chronograph. The thermometer leads were of gold for the third series and

of copper for the other two. When examined microscopically the copper showed only a small quantity of cuprous oxide inclusions.

The results of the measurements showed that the resistance of the copper varied continuously from 0 to 100 deg. C., and that it was probably not in a metastable state.

Coke

The Sulphur Content of Coke.—In a paper presented at the New York meeting of the American Institute of Mining Engineers, February, 1916, Mr. J. R. CAMPBELL describes the effect of aeration and quenching on the sulphur content of coke. Sulphur is known to exist in coal as sulphides, sulphates, and as organic sulphur. For most coking coals the greater part of the sulphur can be safely assumed to be in the form of pyrite FeS_2 . When exposed to the low temperatures in the coking process one or both of the following reactions take place:



The first equation gives the magnetic pyrrhotite and sulphur, while the second, which is the more commonly accepted one, gives straight iron sulphide and sulphur.

In the beehive method, air is introduced in sufficient amounts to carry on the distilling and coking processes, and the sulphur is oxidized, along with the other volatile products. For coals of about 30 per cent volatile matter the ratio of air to gas is $3\frac{1}{2}$ to 1, so that a low grade producer gas issues from the trunnel head. The sulphur remaining in the coking mass as iron sulphide cannot in any way be affected by the aeration or draft on the oven. The old saying common among beehive oven operators, "the hotter the oven the more sulphur burned out" probably never was true unless aeration was carried to complete combustion of not only the gases but the fixed carbon itself, in which case the iron sulphide would be oxidized to Fe_2O_3 . This would give an abnormally low yield of coke. As far as pyritic sulphur is concerned no amount of superaeration will produce increased elimination of sulphur at the low temperatures of distillation. If coking proceeds too quickly or if the heat is irregular, the desulphurization is apt to be less complete, due to the formation of compounds on which heat has no effect.

In the by-product oven no air is supplied and as good an elimination of the sulphur is obtained. This shows the fallacy of superaerating beehive ovens. Sulphur existing in sulphates and as organic sulphur is likewise not affected by aeration.

Quenching should theoretically remove considerable sulphur, but it has been the author's experience that very little was removed in this manner. According to the equation $\text{FeS} + \text{H}_2\text{O} = \text{FeO} + \text{H}_2\text{S}$, sulphur should be eliminated, and the odor of H_2S is noticed, but the coke mass cools very quickly, and its structure prevents the rapid penetration of the water, and as the temperature is lowered the reaction slows up. Quenching is essentially a cooling process.

Hydrochloric acid, when added to the water, greatly facilitates the removal of sulphur, as it readily attacks iron sulphide. This is a fact not generally known. The cost has usually prohibited this method, but with the low-sulphur coking coals disappearing this method may become important.

The C. W. Hunt Company, Inc., West New Brighton, N. Y., has issued a new valve catalog No. 15-3. This catalog contains illustrations and descriptions of its standard types of gates and valves for controlling the flow of bulk materials, such as coal, ashes, coke, ore, stone, sand, gravel, etc.

Recent Chemical and Metallurgical Patents

Electric Furnaces

Electric Furnace for Making Graphite.—An electric graphite furnace which is designed to effect heat savings by preheating the coke charge is patented by JOHN W. BROWN, of Lakewood, Ohio, and assigned to the National Carbon Co., of Cleveland, Ohio. The furnace is a continuous one, the coke charge being fed into the top by a screw conveyor and removed at the bottom by the same means. One form of the furnace is shown in Fig. 1.

The furnace walls are made so as to contain a hollow space, 7, connecting with the charge, at the top of the

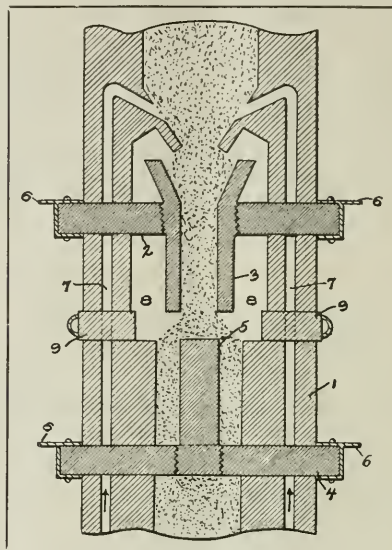


FIG. 1—GRAPHITE FURNACE

furnace. Air or an inert gas is led into the hollow space at the bottom, and is heated by the finished charge which it cools. The gas then goes to the top of the furnace, where it preheats the charge, and emerges in a practically cool state. If air is used, a part of the charge will burn, thereby heating it up considerably, but not enough to graphitize it. The central zone, 3, of the furnace is made of carbon and is connected to electrodes, 6, which furnish the heat necessary to graphitize the carbon. The bottom electrode is shown at 5. The carbon and the coke at the central zone together form the resistor. Several different ways of preheating the charge are mentioned, as follows: By the combustion of a part of the charge itself, by inert gases, by gases passed both through the charge and the walls, by burning hot gases in the upper part of the furnace, and by combinations of these methods. A space just below the central heating zone is provided in which volatile matter can condense, and it is removed through an opening in the side of the furnace from time to time. (1,177,680, Apr. 4, 1916.)

Electric Heat-Treating Furnace.—An electrical resistance furnace for heat treating is patented by T. F. BAILEY and F. T. COPE, of Alliance, Ohio, and assigned to The Electric Furnace Company of Alliance, Ohio. In this furnace the heat from granular carbon resistance elements is reflected from an arched roof down onto the

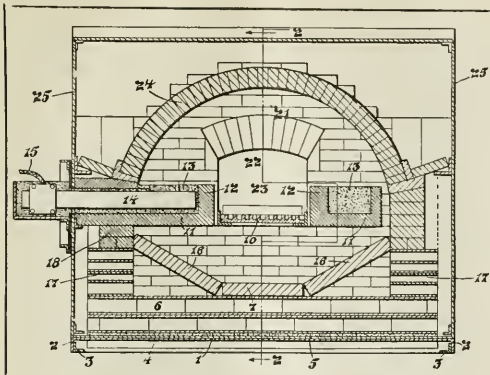


FIG. 2—ELECTRIC HEAT-TREATMENT FURNACE

hearth which contains the material to be heated. A cross-section of the furnace is shown in Fig. 2. The outer casing is of metal and the inner furnace structure is of brick. Extending the length of the furnace and on each side of the middle space, 23, are troughs, 12, containing granular coke or charcoal. Electrodes, 14, are placed at each end of these resistance elements. The heat from the carbon rises and strikes the arched roof, from which it is reflected down onto the hearth. Inclined walls, 16, are also located below the resistance elements in order to reflect the heat which is radiated downward back to the hearth. (1,176,018, Mar. 21, 1916.)

Roasting or Sintering Apparatus Using Electric Heating.—A continuous apparatus for roasting or sintering ores working on the down-draft principle and with "electric firing" is patented by WILLIAM H. HAMPTON, of New York City (assigned to the Conley Electric Furnace Company, Inc., of Wilmington, Del.) The ore or ore mixture is fed from bins into an endless chain conveyor composed of box or trough-like sections hinged together and perforated at the bottom. The ore is then transported along a straight or curved path to a point of discharge. During their course the sections pass over a suction arrangement, which consists of a compartment beneath the conveyor, connected to a suction pump. The top of the compartment is perforated. Above this compartment and above the conveyor is a heating compartment containing electrical resistances. Air passes into this heating compartment, is heated and then passes down through the ore by the suction which causes the down-draft. The heating resistances are made of 60 per cent clay and 40 per cent carbon. If the ore contains sufficient combustible material to need only initial ignition, thereafter burning itself, it can easily be treated by this method. The air necessary to continue the combustion can be supplied from an adjacent compartment either as cold or hot air. If the operation is not to be a sintering one, agitation may be used. It is claimed that ores with less sulphur content than ordinarily used can be roasted and sintered, and that in cases where fuel is needed, less will be used with this process. (1,171,117, Feb. 8, 1916.)

Nitric Acid from Air

Nitrogen Fixation Process.—A boiler having a nitrogen fixation furnace placed inside and integral with it, in order to utilize the excess heat either in the generation of steam, or in the evaporation of solutions, is patented by HANS SCHEFTLEIN, of Christiania, Norway (assigned to Norsk Hydroelektrisk Kvaestofaktiesels-

skab, of Christiania, Norway). This apparatus is claimed to avoid the drawbacks of previous systems for utilizing the heat of the gases issuing from nitrogen furnaces. In some of these systems the gases have been conducted through boiler plants, but the large cost of installation and the relatively large space required, as well as the losses of heat caused by the passage of the gases through pipes or channels have reduced the efficiency of these systems considerably. In the present process it is proposed to place several nitrogen furnaces (Schoenherr type) in separate flues in a vertical boiler, so that the nitrogen furnace replaces the firebox. (1,180,545, April 25, 1916.)

Ozone

Treating Oils, Greases and Fats with Ozone.—An apparatus for treating oils, or liquefied greases and fats with nascent ozone is patented by ALBERT BREYDEL, of Brussels, Belgium. The apparatus consists of a rectangular vessel, holding the oil, or other liquid to be treated. At the bottom of the vessel an electrode is held between two dielectric plates. A short distance above it is placed another electrode made of hollow material, not subject to attack by ozone, and containing small perforations. Air or oxygen is forced through this upper electrode, and, passing through the perforations, ozone is formed at the surface of the upper electrode. This system is claimed to give a good circulation and to work at any temperature without a cooling medium being required. (1,180,372, April 25, 1916.)

Zinc and Lead

Process of Briquetting Zinc Ores and Waste Products.—The preparation of finely divided zinc ores, zinc dust, ash, trimmings and other forms of waste material containing zinc, for treatment in electric or retort furnaces, is patented by OTTO KIPPE, of Osnabrück, Germany. The materials mentioned are briquetted with from $\frac{1}{4}$ to 2 per cent of a soluble salt, such as the chloride or sulphate of magnesium, calcium, iron or zinc. The briquets thus formed are coherent and hard, and are ready for smelting in a short time. (1,168,401, Jan. 18, 1916.)

A special form of briquet for zinc ores, particularly suited to retort distillation, is patented by OTTO BALTIN, of Lipine, Germany. The ore and reducing agent are formed into egg-shaped briquets which are so small that the sum of their exposed surface is many times that of the receptacle used in distillation. When charged into a retort these briquets have only one point of contact with each other, and expose practically their entire surface to the direction action of heat. Ample space is left between them for the easy escape of zinc vapors. (1,166,170, Dec. 28, 1916.)

Treatment of Zinc Ore in Electric Furnaces.—A difficulty encountered in treating an ore charge in an electric furnace is the formation of crusts of slag or other material in the proximity of the tap-hole. In order to obviate this trouble, EDWARD S. BERGLUND, of Trollhättan, Sweden, proposes to add to the furnace at intervals certain easily fusible materials that will combine with the melt and stiff-crusts. Thus in the case of zinc ore he adds 200 kg. of fluorspar to a charge of 1000 kg. of ore and carbon, mixing them intimately before charging; or he may add such fluxes as fluorspar, lime and old slag just before the furnace is tapped, introducing the substances in proximity to the tap-hole. (1,160,244, Nov. 16, 1915.)

Refining Leady Matte.—The customary manner of handling leady matte is to blow off the lead and other volatile impurities in a converter and catch the volatile

In many instances it was possible to do so only after adding a small amount of one of the true wood oils. There is some difficulty in getting the thick heavy coal tar to mix well with the pulp, so that it is not the most desirable medium, and for that reason the coal creosotes have met with more favor. Consequently, most of the gas plants throughout the country have been able to contract for their output of creosote for some time to come. A similar condition prevails with regard to most of the wood oils. There has been somewhat of a rush in the mining industry for contracts for these products in order that proposed mills will be assured of being able to operate. When Germany gets into the coal creosote market again there will doubtless be lower prices for that particular product.

The petroleum men have not been slow to seek the flotation oil market, but their products have not as yet met with much success when used alone. It is possible to mix small amounts of pine oil or creosote with various petroleum products such as stove oil and to obtain flotation with some degree of success, but the general tendency of petroleum products is to float both gangue and mineral non-selectively. The petroleum products that have met with the most success are some of the crude oils, such as Texas crude, and especially certain high-sulphur crude petroleum, obtainable in Kansas and in California. "Stove oil" has met with some success in the copper-concentrating mills, as copper minerals do not have to be concentrated to the same degree of purity as do the lead and zinc minerals. It is probable that, for the wood oils, the copper mills will be able to use cheaper substitutes, such as petroleum products, than will the mills treating baser metals.

One other product that has met success has been the "kerosene acid sludge" from certain of the petroleum refineries. This material is the resultant of the removal of certain impurities with sulphuric acid and often consists of as much as 50 per cent sulphuric acid. Not all of the acid sludge products have proven suitable, only the California sludge being sold at present.

Just how far all this substitution will be successful is not known and there is no way to predict. The test work of the coming year should go far toward solving this problem.

PRODUCERS OF OILS MORE OR LESS ADAPTED TO FLOTATION

Following is a list of dealers in different oils who have placed on the market various products. A host of these dealers are prepared to supply these products at any time, and of fairly uniform quality. None of them has been able to exactly duplicate their carload shipments, so that the general practice is to test each shipment of oil in a laboratory testing device to determine the proper method of using a given shipment of oil. This non-uniformity of shipments will doubtless vanish when the market becomes steady.

Wood Oils

Pine oils, rosin oils, wood creosotes, tar oils, turpentine, etc.:

1. Pensacola Tar & Turpentine Co., Gull Point, Fla.
2. General Naval Stores Co., New York.
3. Georgia Pine & Turpentine Co., 158 Perry Street, New York.
4. Central Distilling Co., Helena, Ark.
5. United Naval Stores Co., Helena, N. Y.
6. American Tar & Turpentine Co., New Orleans, La.
7. Cleveland Cliffs Iron Co., Cleveland, Ohio.
8. Chesapeake Tar & Rosin Co., Baltimore, Md.
9. Custer City Chemical Co., Custer City, Pa.
10. Yaryan Naval Stores Co., Brunswick, Ga.
11. Hussay & O'Connell, Savannah, Ga.
12. Florida Wood Products Co., Jacksonville, Fla.

13. Oregon Wood Distilling Co., Portland, Ore.
14. National Wood Products Co., Wilmington, N. C.
15. Chapman Manufacturing Co., Savannah, Ga.
16. Spiritine Chemical Co., Wilmington, N. C.

Eucalyptus oil:

17. Atkins, Kroll & Co., San Francisco, Cal.
- And other importers.

Coal Tar, Coal Creosotes, and Aromatic Hydrocarbons

1. The Barrett Co., New York.
2. F. J. Lewis Manufacturing Co., Chicago, Ill.
3. American Creosoting Co., New Orleans, La.
4. American Tar Products Co., Chicago, Ill., and St. Louis, Mo.
5. Republic Creosoting Co., Indianapolis, Ind., and Minneapolis, Minn.
6. American Coal Refining Co., Denver, Col.
7. Numerous municipal and similar coal-gas plants.
8. Numerous by-product coke ovens, such as:
 - Pennsylvania Steel Co., Steelton, Pa.
 - National Tube Co., Penwood, W. Va.
 - Milwaukee Coke & Gas Co., Milwaukee, Wis.
 - Pennsylvania Steel Co., Lebanon, Pa.
 - Solvay Process Co., Syracuse, N. Y.
 - By-Products Coke Corporation, South Chicago, Ill.
 - Semet-Solvay Co., Detroit, Mich.
 - Central Iron & Coal Co., Tuscaloosa, Ala.
 - New England Gas & Coke Co., Everett, Mass.
 - Illinois Steel Co., Joliet, Ill.
 - Maryland Steel Co., Sparrows Point, Md.

Vegetable Oils

1. Cottonseed oil, etc.—Southern Cottonseed Oil Co., New York.
2. Corn oil—Corn Products Company, New York.
3. Palm oil—Peter van Schaack & Co., Chicago, Ill.

Animal Oils (Fatty Acids)

1. Oleic acid—Peter van Schaack & Co., Chicago, Ill.
2. Oil flotation grease emulsion—Mohawk Refining Co., Cleveland, Ohio.

Petroleum Products (Crude, Asphaltum Base)

1. California crude—Union Oil Co., Santa Paula, Cal.
 - Association Oil Co., Los Angeles, Cal.
 - Standard Oil Co., Richmond, Cal.
2. Road Oil No. 80—Harris Oil Co., Los Angeles, Cal.

Reconstructed Petroleum Oils

1. Special mineral separator—Continental Oil Co., Salt Lake City, Utah.
2. Solulene and minolene—Star Lubricating Co., Salt Lake City, Utah.

Refined Petroleum Products

1. Stove oil—Standard Oil Co., San Francisco, Cal.
2. Stanolind, etc.—Continental Oil Co., Salt Lake City, Utah.
3. Flotation oils—Utah Oil Refining Co., Salt Lake City, Utah.
4. Heavy mineral flotation oils—Geo. P. Jones & Co., St. Louis, Mo.
5. Refinery acid sludge—Any refinery.
6. Lubricating oils—Any company.

Special Mixtures of Mineral and Wood Oils

1. Calol oils—Standard Oil Co., Richmond, Cal.
2. Mine & Smelter Supply Co., Denver, Col.
3. Hendrie & Bolthoff Manufacturing & Supply Co., Denver, Col.

Costs of Flotation Oils

The costs of flotation oils have varied so much, owing to the unsettled market, that it is almost impossible to give an idea of what they should cost. For a rough estimate it is possible to say that crude petroleum will cost the same as for other purposes. Many of the

specialized products such as coal tar listed above will cost about 5 cents or less per gallon. The coal creosotes and the wood creosotes cost 15 to 30 cents per gallon; the pine oils 45 to 60 cents per gallon, and eucalyptus oil will cost \$1.50 or more per gallon. The effect of the ending of the war as regards coal tar and creosote in the American market is uncertain but, so far as known, wood products will not be affected, and petroleum products for flotation will almost certainly be little affected. Flotation men do not like to have their oil costs go over 5 cents per ton of slimes treated, and many costs are nearer to 2 cents, or possibly even less.

OILS ADAPTED TO CERTAIN ORES

There can be no doubt that the higher grade pine oils and other wood oils are the best adapted to general flotation work, but the question of what is commercially feasible is entirely different. Thus, the wood creosotes are meeting much favor. Many of the special petroleum products, especially those high in sulphur, are adaptable for rough concentration of copper ores, but the most favored materials for such ores at present seem to be the coal-tar products in combination with topped crude petroleum, oils from which the lighter fractions have been removed by distillation. Coal tars and creosotes, with a small addition of pine oils, are being used a great deal in zinc work, and the wood creosotes find favor in the treatment of galena ores. Gold and silver ores seem to require much pine oil, although the pine oil can be diluted with some of the coal creosote oils.

It will be found that there is a considerable number of oils that will give good results on any given ore, if the mechanical treatment is adjusted to suit each given oil. The selection of the proper oil in any case is purely a matter of experiment. Local conditions, such as transportation, also influence considerably the choice of oils.

CONSUMPTION OF FLOTATION OILS

Following is a table showing the amount of flotation oils being consumed every month throughout the United States. These figures were collected at the beginning of 1916 by direct communication with the companies. The tonnage of ore being treated was also estimated, and proposed increases allowed an estimate of the probable tonnage by the end of 1916. Owing to the fact that some of the companies were secretive, on account

MONTHLY CONSUMPTION OF FLOTATION OILS IN UNITED STATES

Type of Ore	MONTHLY TONNAGE OF ORE		MONTHLY CONSUMPTION OF FLOTATION OILS, BEGINNING OF 1916, POUNDS					
	Begin- ning 1916, Tons	End of 1916, Esti- mated, Tons	WOOD PRODUCTS					
			Pine Oil	Pine Tar Oil	Euca- lyptus	Creo- sote	Tur- pe- tine	
Copper.....	1,248,000	1,942,000	59,300	750	.....	417,000	1,503	
Zinc and complex.....	248,000	350,000	60,750	667	.....	262,500	3,330	
Lead.....	115,000	136,000	3,900	.....	216	121,090	.....	
Gold and silver.....	45,700	213,000	8,830	750	.....	40,250	.....	
	1,656,700	2,551,000	133,780	2167	216	840,750	4,830	

MONTHLY CONSUMPTION OF FLOTATION OILS, BEGINNING OF 1916, POUNDS

Type of Ore	Oleic Acid	COAL PRODUCTS			PETROLEUM	
		Tar	Creosote	Cresol	Crude	Fractions
Copper.....	.....	677,000	403,000	8,340	79,000	1,702,000
Zinc and complex.....	5,830	10,670	46,500	.....	157,000	41,000
Lead.....	.....	.....	9,250	.....	.....	660
Gold and silver.....	.....	27,450	4,920	.....	7,090	6,250
	5,830	715,120	463,670	8,340	243,090	1,749,910

of the litigation situation, the figures are probably in error as much as 20 per cent in either direction and can probably be made more accurate as time goes on.

The products called "Pine oil" probably include a considerable amount of the lighter fractions of pine tar oil.

High-Temperature Furnace Cement

Before the Philadelphia Foundrymen's Association Mr. W. T. Quigley delivered recently an interesting experimental lecture on tests of high-temperature furnace cement.

In tests made by the Bureau of Standards on the melting points of the best brands of fire-clay brick, only one fire-clay brick out of 56 samples withstood a temperature of 3135 deg. F. before it melted; the average was considerably below 3000 deg. F. But ability to withstand high temperature is not the only characteristic to be considered. Brick should be selected for the special duty required and should be laid in a material which will provide a bond of equal strength with the brick, having the same coefficient of expansion and contraction and capable of withstanding equal temperature without deterioration.

A mixture of fire clay and water has absolutely no binding strength. This is a serious matter. Usually the falling of an arch, the bulging of a wall or excessive cutting away of a portion of the interior of a furnace can be attributed to a defect in the joints. The fire clay disintegrates or falls out, allowing the heat to work in between and attack the lining and shorten its life. Very often an arch is lost because the clay becomes loosened around one of the roof brick and when it falls the whole structure is weakened.

Mr. Quigley explained the advantages of the use of "hytempite" furnace cement. It forms a lasting union, sets at normal temperatures, that is, air sets, and retains its strength regardless of the heat to which it is subjected. Tests have proven that hytempite furnace cement used as a binder (in place of fire clay) when air set forms a joint as strong as the material united, and that the strength is not impaired but increased by the action of heat.

Hytempite furnace cement withstands the cutting action of flames and is especially adapted for oil furnaces when the gases are generally of high velocity, for furnace roofs, door arches, bung tops, boiler settings, etc. It can also be used as a coating or wash to smoothen and harden the surface of a furnace lining to protect it from abrasion; in fact, it can be used wherever fire-clay bricks are used.

Mr. Quigley made some interesting experiments in electric furnaces of the Electric Heating Apparatus Company, using thermo-electric and radiation pyrometers of the Thwing Instrument Company.

Two pieces of Jersey clay fire brick were put together with a Jersey clay and Pennsylvania clay fire brick with a Pennsylvania clay, both the clay and brick being from the same works in each instance. After dried and heated to 2000 deg. F. they were found to fall apart upon the slightest handling.

On the other hand, when hytempite furnace cement was used in various experiments with different brands of fire-clay bricks, it was found that this cement not only withstands abnormally high temperatures, but that it forms a permanent bond between the pieces united and continues to do so from normal temperatures to as high a temperature as the refractory material united with it will withstand, without injuring the brick or acting as a flux at any temperatures that the brick itself withstands.

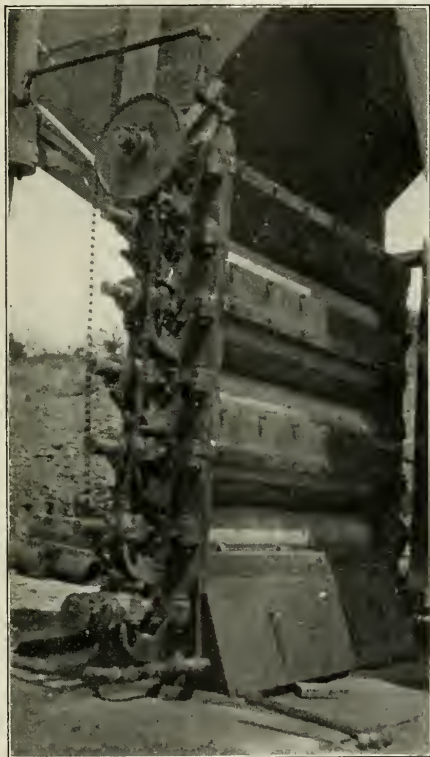
A New Dry Amalgamator

LEROY A. PALMER

The accompanying illustration shows a dry amalgamator invented by Frederick O'Brien of Searchlight, Nevada, and being tried out by him on the slimes from the Duplex dump at that place.

The machine consists essentially of five amalgamated copper cylinders, each 6 x 48 in., three of which can be seen in the illustration. Beneath each cylinder is a shallow curved amalgamated trough containing a bath of mercury in which the lower part of the cylinder is submerged.

The hopper shown has a longitudinal feed slot in the bottom from which the fine slime feeds to a roller the same size as the others, but not amalgamated, with



DRY AMALGAMATOR AT SEARCHLIGHT, NEVADA

twelve helical ribs of very long pitch. These ribs, passing under the slot in the hopper take out a gradual and uniform feed for delivery to the amalgamated rollers.

The latter are actuated by chain and sprocket by which each revolves in a direction opposite to those next to it, the speed varying from 75 r.p.m. on the top roller to 35 on the bottom.

The inside of the iron frame is so cast as to form a guide by which the thin pulp stream is directed so as to strike the amalgamated cylinder just back of the top, so that as the cylinder revolves the pulp is carried over, clinging to it until it reaches nearly the bottom point. Here it drops off and is directed against the next cylinder where the process is repeated, so that the

pulp stream comes in contact with practically half of the surface of each cylinder as it passes.

As mentioned each cylinder has a curved amalgamated trough beneath it. This trough contains a bath of mercury so that as the cylinder passes through it the amalgam which has formed on the surface is dissolved in this bath. As the cylinder passes out of the bath it rubs against a felt scraper which removes the excess of quicksilver, sands and other impurities which may have clung to it so that they drop back into the mercury bath.

The agitation of the bath by the cylinder passing through it is sufficient to float these impurities and they are drawn off by means of a suction through a pipe with a number of small nozzles projecting downward almost to the surface of the mercury. The housing of the machine is cast with a water jacket in each section through which the hot water from the water jacket of the gasoline engine is circulated as an aid to amalgamation. A machine can be made up of as many cylinders as desired.

The pulp or tailings finally discharge to a vacuum box at the bottom where the heavier particles settle and are removed by a screw and the lighter are drawn off by suction. In cleaning up it is only necessary to open the machine in front of one roller at a time, remove the curved trough and put in another, which can be done without interrupting operations.

Five rollers, each 6 x 48 in., presenting one-half of the surface for actual contact with the pulp stream would have an effective amalgamating surface of 16 sq. ft. This would be considered a small plate surface following a battery but it is claimed in this machine that this surface, by passing through the bath and under the felt rubber, is always clean and live whereas a stationary battery plate besides becoming fouled quickly picks up a certain amount of sand and other impurities by which its effective area is reduced. Thus the four square feet of this dry amalgamator are equivalent to a considerably larger area of plate surface.

So far as the principle of this machine is concerned it appears feasible. As to actual operation it is still in the trial stage. It was tried out on the Duplex dump and made a saving of 50 per cent but it was found that the cylinders had not been made true and consequently were not accomplishing what they should. It seems reasonable to believe that with the working out of minor details such a machine should find a valuable place in the dry camps.

San Francisco, Cal.

A New Oxygen and Nitrogen Company

The Air Reduction Company, 50 Broad Street, New York, recently incorporated with a capital stock of \$2,500,000, has acquired the American rights to the Claude process for making liquid air and for separating the oxygen and nitrogen of the air (see article on "Refrigeration in France" by L. Marchis, Met. & Chem., Vol. XIII, pp. 187 and 312). The company has purchased control of the Superior Oxygen Company, which is the second largest producer in the country, and will operate the plants of the Superior company. Six new plants to use the Claude process will be finished and in operation in five months and inside of a year the company expects to have plants all over the country. When all of these new plants are completed the new company will be the largest producer of oxygen in the world.

On the board of directors are Percy A. Rockefeller; W. T. Hollingsworth, representative of the Westinghouse Company in Europe; Lorenzo Semple, counsel for the French government; Ambrose I. Monell, presi-

dent of the International Nickel Company, representatives of the Société de l'Air Liquide of France, and Walter W. Birge of St. Louis, who is the present active head of the company.

Mr. Birge says that the company will concentrate its efforts first on oxygen, which is a big field, especially in oxy-acetylene use. The company has engineers in Europe investigating the calcium carbide situation with a view to manufacturing this commodity, probably in Europe, for making acetylene for use in the oxy-acetylene burner for welding and cutting. The company may also make compressed acetylene, if they take up the carbide manufacture.

Another important field which the company will enter, after having the oxygen business thoroughly organized, is the production of nitrogen, cyanamid, ammonia nitrates and nitric acid. Two or three processes for making nitric acid are being tried out at the present time and the experiments are well under way. The South is a big field for fertilizer and the company expects to establish nitrate manufacture in the South either by one central plant or several distributed plants.

It is expected that the capital stock will shortly be considerably increased.

A New Foundry Equipment Firm

Leyshon & Lane, Inc., has recently been organized to take over the oven and special foundry equipment business which has grown out of Mr. H. M. Lane's foundry research work.

The H. M. Lane Company was organized several years ago to do foundry consulting engineering work, to design new foundries, or to plan improvements for old foundries. It was not the intention that this company should become a contracting or manufacturing organization, but in connection with the betterment work carried on in foundries, various devices were required and special equipment needed which could not be obtained on the market. Some of these have been taken over by regular manufacturers, and some of them were patented by H. M. Lane, particularly the forced draft core and mold oven system.

One installation has sold another until a considerable business has grown out of this line, and recognizing the field, Leyshon & Lane, Inc., has been organized to contract for complete foundry installations, to install melting furnaces, annealing ovens, core ovens, mold ovens and handling appliances. Mr. T. A. Leyshon, who has been associated with Mr. H. M. Lane for several years, is president of the new organization; and Mr. C. T. Holcroft, who has been in the furnace building business for many years, first in the Chester, Pa., district, next in the Pittsburgh district, and later in Detroit, is treasurer. The new company has made arrangements for a portion of Mr. Lane's time so that he can act as consulting engineer on any problems they may have.

The H. M. Lane Company will continue as a consulting organization under the personal charge of Mr. H. M. Lane. The organization of the new company will free Mr. Lane of direct responsibility for the oven business and give him more time for consulting practice.

Personal

Mr. L. G. E. Bignell, formerly sales manager for the Denver Engineering Works and for the past three years engineer for the Mine & Smelter Supply Company at El Paso, has accepted a position with the Colorado Iron Works at Denver as sales engineer, and assumed his new duties June 1.

Dr. Charles Blanc, expert organic chemist, has be-

come connected with Messrs. Moses, Pope & Messer of 366 Fifth Avenue, New York City, in the capacity of a consulting chemist.

Mr. N. C. Harrison, formerly steam engineer at the Pittsburgh Crucible Steel Company, has been made general superintendent of the Atlantic Steel Company, Atlanta, Ga.

Mr. Weston B. Lazear has recently assumed charge of the New York office of the Stephens-Adamson Company. Mr. Lazear has devoted the past seven years to the design of "S-A" conveying, elevating, screening and transmission machinery. Various stages of his experience cover a period as draftsman, then chief draftsman, and later sales engineer. In the latter capacity he has been associated with the New York office for the past year.

Mr. S. Naganuma has opened an office in the Equitable Building, 120 Broadway, New York, as representative of Mitsubishi Goshi Karsha, mining and shipping firm of Japan.

Dr. J. F. Norris, of the department of chemistry at Vanderbilt University, has accepted an offer from the Massachusetts Institute of Technology to take charge of research work and applied chemistry with fifth-year students in the new chemical engineering course which starts next fall. Dr. Norris formerly taught for five years at the Institute. He was recently appointed by Secretary of the Navy Daniels as one of the members of the Tennessee State Board of Industrial Organization for Preparedness.

Mr. Stanley H. Rose, until recently in charge of the New York office of the Bureau of Foreign and Domestic Commerce of the Department of Commerce, has been engaged by the Barber Asphalt Paving Company to direct its foreign trade department. Prior to his appointment as commercial agent of the bureau Mr. Rose had had an extensive business experience in the larger part of Europe, Australia, New Zealand, India and Egypt, and has also held important posts with American and European firms engaged in foreign trade. He is considered an expert in foreign tariffs, trade regulations and shipping. As special agent of the Bureau of Foreign and Domestic Commerce, Mr. Rose has just completed a tour of more than fifty cities of the Middle West, South and Southwest, acquainting manufacturers with foreign trade opportunities and advising commercial organizations as to the best methods of promoting export trade. Mr. Rose was educated in London, Berlin, Paris and Brussels, and speaks most of the modern languages.

Mr. Lyon Smith, formerly metallurgist of the Pittsburgh-Silver Peak Gold Mining Company, has been appointed metallurgist for the Snyder Electric Furnace Company of Chicago.

Mr. G. H. Stephens, until recently vice-president and Eastern manager of Stephens-Adamson Manufacturing Company, has retired from active business on account of ill health. Mr. Stephens has been prominent in the conveying industry for twenty-five years, and has enjoyed a wide acquaintance among machinery users of the East.

Obituary

John Edson Sweet, president of the Straight Line Engine Company, Syracuse, N. Y., and for several years professor of mechanical engineering at Cornell University, died at his home in Syracuse, on May 8. He was best known as a founder of The American Society of Mechanical Engineers and designer of straight line engines. He was born in Pompey, N. Y. on October 21, 1832, and received most of his early education in the

district schools. Up until 1872 he worked in various mechanical lines, mostly in railroad shopwork and draughting. He also spent some time in England and France, and in 1871 and 1872 designed his first straight line engine. In 1873 he took up teaching work at Cornell, which he continued until 1879. He was instrumental in organizing the American Society of Mechanical Engineers in 1880, of which he was president in 1883-4. He was the recipient of the John Fritz medal in 1914 (see our vol. XIII, p. 75) and in 1914 received the degree of Doctor of Engineering from Syracuse University. He was also a member of the Advisory Board of the New York State Branch, National Society for the Promotion of Industrial Education.

Mr. George M. Kendall, for a number of years manager of the New York office of the Pfaudler Company and widely known among the chemical and pharmaceutical trades, died on Monday, May 22, at the home of his father in Ludlow, Vt. Mr. Kendall had suffered for more than a year from a complication of diseases, which caused his death, and his inability to engage actively in the service of the firm with which he had so long been connected was a sore trial to him. He was an exceptionally energetic and aggressive worker, firm in his convictions, and guided in all his dealings by a strict "New England conscience." Even while confined to his bed, he continued to keep in touch with his office, and to inject his forceful personality into its activities.

Industrial Notes

New Evaporating Plant.—The new evaporating plant installed by the Penobscot Chemical Fibre Company at Great Works, Me., has been working very satisfactorily. The builders of this apparatus advise that it contains improvements in the methods of handling caustic soda from electrolytic cells and has been designed for the special purpose of operating in conjunction with the Larchar cell. The Swenson Evaporator Company built and installed these evaporators, and after successfully operating same secured a contract for a new large quadruple effect for the soda recovery system.

The Hoskins Manufacturing Company, Detroit, Mich., due to the increasing demand for Hoskins electric furnaces, pyrometers, hot plates, and chromel resistor material, has opened a branch office in Boston at 613 Equity Building, 185 Devonshire Street, in charge of Mr. J. E. Hines. This is the third branch office the Hoskins company has opened in the East. Other branches are being maintained at 3709 Grand Central Terminal, New York, in charge of F. L. Zimmerman; 1404 Oliver Building, Pittsburgh, in charge of W. C. Tharp, and 1610 Otis Building, Chicago, in charge of C. F. Busse.

Balances.—The various American makers of assay balances have developed their methods of manufacture to the point that their product for the exacting conditions of use in the assay office far excels that of European makers, who are less familiar with the special requirements of the assayer. As illustrating, in one case, the careful work done, the G. P. Keller Manufacturing Company of Salt Lake City exhibited a set of standard assay weights at the Panama-Pacific International Exposition which the Bureau of Standards certified to as follows:

Weight	Correction	Weight	Correction
500 mg.	—0.001 mg.	10 mg.	—0.001 mg.
200 mg.	0.000 mg.	10 mg.	—0.001 mg.
100 mg.	+0.003 mg.	5 mg.	0.000 mg.
100 mg.	0.000 mg.	2 mg.	0.000 mg.
50 mg.	—0.002 mg.	2 mg.	—0.005 mg.
20 mg.	—0.001 mg.	1 mg.	—0.001 mg.

Reduced Production of Turpentine and Rosin.—The preliminary statement issued by the United States Bureau of the Census of the 1914 census of manufactures with reference to the turpentine and rosin industry in this country shows that the production during 1914 was considerably less than during 1909, according to Commerce Reports. Reports were received from 1392 turpentine distilleries. Their total output was valued at \$20,968,684 and consisted of 26,980,981 gal. of spirits of turpentine, valued at \$10,510,407; 2,885,077 barrels of rosin, valued at \$10,332,700, and dross, valued at \$125,577. The census of 1909 gave reports from 1585 distilleries, and their total production was valued at \$25,295,017, about evenly divided between spirits of turpentine and rosin. The figures for 1914, including besides those mentioned the products of lumber manufacturing and wood-distillation plants, compared with the amounts for 1909, show decreases of 16.1 per cent in total value, 6.9 per cent in quantity of spirits, 16.8 per cent in value of spirits, 9.8 per cent in quantity of rosin, and 15.9 per cent in value of rosin, and an increase of 96.3 per cent in value of dross.

The Trill Indicator Company of Corry, Pa., has issued a new 56-page publication on engine indicators and indicating. The book is instructively illustrated and describes in detail the construction and purpose of the several parts of both the outside and inclosed spring types of indicators, including indicator reducing motion. Considerable space is given to discussion and data on indicator springs, and full instructions on indicating and interpreting cards from all types of engines, high-pressure steam, gas and fuel oil engines, triple-expansion and compound engines, and ammonia compressors. Detailed instructions are given on the application and use of the indicator and the planimeter, with easily understandable instruction on the few arithmetical calculations that are necessary. There are fifteen pages illustrating and discussing the characteristic diagrams of the several types of engines including the latest four-valve engines of the new Poppet Valve type, the Uniflow engine, high-compression two-cycle oil engine, and the Diesel engine; also a large number of faulty diagrams illustrating the characteristic faults of engines.

The Ha Ha Baie Sulphite Company of Chicoutimi, Province of Quebec, Canada, has announced the awarding of the contract for the construction of its new paper pulp plant at Bagotville, Chicoutimi County, Province of Quebec, Canada, to the J. G. White Engineering Company of New York, under the direction and design of Mr. Hardy S. Ferguson, paper mill engineer, also of New York. This plant, which marks a decided step in the pulp manufacturing activities of northeastern Canada, will embody the latest improvements in design, and the initial installation will have a capacity of 120 tons of sulphite pulp per day. The mill buildings, of brick, concrete and steel, will be erected on the shores of Ha Ha Bay, on the Saguenay River, and will occupy a space of approximately 5 acres, and besides the usual rail facilities will be provided with a system of wharves, accommodating ocean-going vessels. Work at the site has begun, and it is expected that the plant will be producing pulp early in 1917. Mr. J. E. A. Dubuc, president of the North American Pulp & Paper Company and general manager of the Chicoutimi Pulp & Paper Company, will be at the head of this new enterprise.

Humidifying.—Bulletin No. 100 entitled "Carrier Humidifying Apparatus," has just been published by the Carrier Engineering Corporation, 39 Cortlandt Street, New York. Briefly, this bulletin explains such details as air supply, fixing the amount of water vapor,

heating, cooling, securing various humidities from one apparatus, air distributing systems based upon ordinary galvanized iron ducts, interior risers, hollow pillars, central vertical flues, automatic dew point control, proportioning fresh and return air, etc. Further detailed description includes features of the Carrier humidifier—spray chamber, piping and nozzles, water pumping, heating and straining methods, air distributing baffles, fan, water eliminating baffles, fresh and return air dampers, compressed air system and safety valves for operating the dew point control, etc.

The Leeds & Northrup Company, Philadelphia, Pa., has issued Bulletin No. 875, describing the "potentiometer" system of pyrometry. The bulletin is nicely illustrated, showing installations of the pyrometer and working parts. A description is also given of the fundamental principle of the potentiometer, the development of the wiring scheme of the cold-end compensator and the automatic compensator. The method of determining transformation points is also described.

The Standard Car Construction Company, St. Louis, Mo., expects to have its new tank car plant at Sharon, Pa., completed and in operation about the first of September. The capacity will be fifteen cars per day, embodying the recent M. C. B. suggestions, i.e., double riveted tank, low running boards and jacking pads for raising underframe underload. The tanks are long, which lowers the center of gravity, and allows the use of 15-in. center still channels, giving the underframe great rigidity.

Crude Barytes Production.—The production of crude barytes in the United States in 1915 was 108,547 short tons, according to the Geological Survey, which is more than twice the 1914 production. There has been a large demand from the newly-established barium chemical industry.

Asbestos.—Asbestos was produced in this country in 1915 to the extent of 1731 short tons valued at \$76,952, according to a Geological Survey report by J. S. Diller. This was a gain over 1914 of 484 tons. Most of our asbestos comes from Canada, and on March 25, 1916, an embargo was placed on shipments which shut off our supply from that quarter. This caused a great hardship, and the embargo has subsequently been modified to some extent to allow shipments to come into this country. Domestic sources are being investigated, and the encouraging outlook in Arizona, with the possible resumption of production in Vermont, together with an increased production from Georgia, may alleviate the situation considerably.

The Deschutes Hydro-Electric Process Company has been organized at Portland, Ore., with a capital of \$350,000, to engage in the fixation of atmospheric nitrogen. The organizers are J. A. Jeffrey, C. D. Charles and E. Ferguson.

Nitre Cake.—As a substitute for sulphuric acid nitre cake is finding many uses. Nitre cake furnished by the E. I. du Pont de Nemours & Company, Wilmington, Del., has the following approximate composition:

	Per Cent
NaH SO ₄	78
Na ₂ SO ₄	18
Moisture	4
FeSO ₄	Trace
Sulphuric acid equivalent, approximate	32
Sulphuric acid equivalent hot saturated solution, approximate	18

The product is variously known as sodium acid sulphate, sodium bisulphate, and acid crystals, and is readily soluble in hot water.

The Goldschmidt Thermit Company announces the removal of its general offices to the Equitable Building, 120 Broadway, New York.

Book Reviews

The Metallurgists' and Chemists' Handbook. Compiled by Donald M. Liddell. 4 x 7 in., 0.7 in. thick, 603 pages, price, \$4. New York: McGraw-Hill Book Co.

The author, as managing editor of *The Engineering and Mining Journal*, had frequent occasion to consult tables of technical data, particularly in answering the thousand and one questions which are directed to such an encyclopedic and ubiquitous personage. Hence the resulting accumulation of useful tables and data, which now appears in pocket-bible form for the use of neophyte and adept. The various sections cover mathematics, price and production statistics, physical constants, chemical data, sampling, assaying, analysis, ore dressing, cyanidation, fuels and refractories, mechanical engineering, construction, general metallurgy, first aid.

The characteristic of the book is that it is not descriptive, but tabular and statistical. It is well selected and very carefully compiled; the author's intelligent discrimination is everywhere in evidence. Speaking as a metallurgist, the reviewer confesses that it is the first metallurgist's handbook which has suggested to him the thought, "Put me in your pocket!"

Elementary Practical Metallurgy. By J. H. Stansbie. 152 pages, 25 illus. Price \$1.40 net. Philadelphia: P. Blakiston's Son & Co.

This interesting and useful book is certainly "elementary," but it is not what is commonly called "practical metallurgy." It would be properly described by the words, "Elementary Experiments for the Metallurgical Laboratory." It tells the student how to construct simple laboratory furnaces, make assays for gold and silver, test fuels, examine clays and slags, make simple mechanical tests, harden and temper steel, reduce a few oxides and sulphides to metal, work the thermit process, and make a number of bronzes, brass and white metal alloys. It is in these directions practically written, but is not very far advanced in scientific reasons or explanations. It might be Pepper's "Play Book of Metals" modernized into an elementary laboratory course.

A Text-Book of Practical Assaying. By James Park. 342 pages, 17 illus. Price \$2.50. Philadelphia: J. B. Lippincott Company.

This is a revision and enlargement of the third New Zealand edition. "The field covered is the customary two years' course of assaying as given in mining and technical schools." It starts in with the most elementary steps, and leads up to the most complex problems of the assayer. But the author includes under the term "assaying" what would not be so considered in the United States, and here a word of explanation is necessary.

Professor Park defines assaying as "the valuation of ores, bullion and metallurgical products," and after saying that no hard and fast line can be drawn between assaying and quantitative chemical analysis, he repeats that "assaying is merely a specialized branch of chemistry dealing with metallurgical products." We are therefore prepared to find wet methods as well as fire assays given for the determination of the metals, such as lead, tin, antimony, bismuth, iron, manganese, zinc, chromium, and nickel. But what excuse is there for including under the author's own definition the analyses of rocks, soils, manures, waters, alcohol, sugar, milk, and petroleum?

The book is good, and a very useful one for a school course in assaying and quantitative analysis, but the author has handicapped it with the misnomer "assaying."





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